THE ECONOMICS OF FEEDING HORSES

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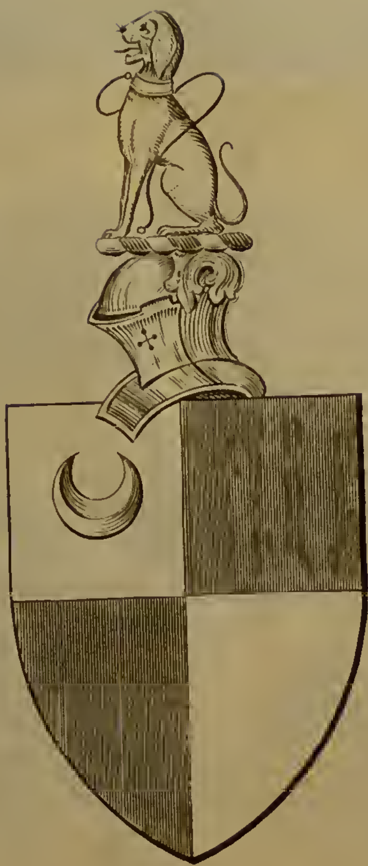

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THE
ECONOMICS OF FEEDING HORSES

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THE ECONOMICS OF FEEDING HORSES

BY

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PREFACE

At the present time the problem of feeding horses so as to secure the maximum of efficiency at the minimum of cost is a very urgent one. The draught horse is competing against methods of mechanical traction, and the question of cost is the decisive factor. For this reason it is incumbent upon horse-owners and managers, and in a special sense upon veterinary surgeons, to know how to feed horses cheaply, and at the same time satisfactorily in other respects. The veterinary surgeon, if consulted, should be able to point the way to great saving in many cases, whilst he should prevent rash experiments in feeding which are sometimes made by directors or managers with disastrous results to the horses.

The subject of scientific feeding has been investigated by many experimenters both in this country and abroad, especially in Germany and the United States. The practical results have been made available for those engaged in feeding cattle, for milk or meat production, in numerous books and agricultural journals. The feeding of horses, on the other hand, has been somewhat neglected.

The information can be found, but it is usually

hidden away in a mass of material of little or no interest to the horse-owner. The present book is intended to deal with the feeding of horses only, and it is further limited to horses used for work. Thus it is hoped that it may prove useful to horse-owners in general; to veterinary students, as an important branch of veterinary hygiene; and to veterinary surgeons. As a teacher of veterinary hygiene for several years, the writer has been made familiar with the difficulties experienced by those reading this subject for the first time. The difficulties have been kept in mind, and an attempt has been made to elucidate them by illustration and analogy as far as possible.

Among the textbooks which have been consulted, and in some cases quoted, special mention must be made of Kellner's "Scientific Feeding of Animals"; also Warrington's "Chemistry of the Farm"; Jordan's "Feeding of Animals"; and F. Smith's "Veterinary Hygiene."

I desire to express my great indebtedness to my friend, Mr. A. W. Noël Pillers, F.R.C.V.S., for many valuable suggestions, for writing the greater part of the chapters on "Feeding and Watering," and "Preparation of Food," and for his careful and critical reading of the proofs. At the same time responsibility for opinions expressed in the book belongs to the author alone.

To my wife my thanks are especially due for much patient labour involved in checking the numerous calcu-

lations throughout the book, and in the construction of the tables.

To my colleague, Dr. G. Druce Lander, thanks are due for some of the analyses of foods, and for valuable suggestions in connection with those chapters dealing more particularly with chemistry.

Whilst the calculations and tables have been repeatedly checked, it is possible that some numerical mistakes still remain. If the kindly reader will point out any he may discover, I shall be obliged, and it will make for accuracy in any future edition.

HAROLD A. WOODRUFF.

ROYAL VETERINARY COLLEGE, LONDON.
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ECONOMICS OF FEEDING HORSES

CHAPTER I.

INTRODUCTION.

The food of an animal is necessary for the purpose of building up the tissues and organs during growth, for making good the wastage due to wear and tear, for keeping up the body temperature, and for supplying the necessary energy both for the vital functions and for any external work the animal may be required to do. During growth, the food most suitable varies with different stages, but must especially provide material for the sufficient production of bone and muscle. Even from birth all the tissues and organs of the body, in carrying out their functions, are subject to wear and tear. Throughout life some of the cells of which the body is made up are wearing out or dying, and these have to be replaced by means of fresh material built up from the food into cells. Thus the food to supply these needs must necessarily contain all the chemical elements found in the normal animal body. Not only is this so, but to be useful these elements must be supplied to the animal in the form of complex organic compounds. It is not

sufficient to provide an animal with carbon or iron, oxygen or nitrogen, in simple form, for, as such, these substances could not be assimilated. They have to be built up into suitable compounds by plants, and then can be used as food for animals. A plant, by means of the energy it derives from the sun, can take in and assimilate into its own tissues simple inorganic substances such as carbon dioxide and water, or salts such as sodium nitrate, and build them up into complex organic bodies; but an animal has no such power. The animal requires the finished products of plant activity as its raw material, and can make no use of the simple substances which serve as the food of plants. Further, the higher animals are all warm-blooded, and have a fixed normal body temperature which in health has to be kept up by means of food. For the purposes of animal heat, food may be looked upon as the fuel keeping up the fire; and just as the heat from a fire may be used to generate steam, which in its turn will do work, so the food supplies energy for the work of the body. Work is being done in the body constantly, whether the animal is asleep or awake, at rest or at work. All the vital processes—such as the beating of the heart to drive the blood round the circulation, the movements of the chest in breathing, the secreting of digestive juices and other glandular products—entail work being done or energy being expended, and are therefore ultimately dependent on the food. Thus it is all important that the food of an animal shall be adequate in quantity and suitable in kind, and, further, in the case of the horse, where the cost of the food is placed against the animal's earning capacity, it must be arranged as economically as possible.

Of all the elements necessary in a complete diet, the most important are carbon, hydrogen, oxygen, and nitrogen, and of these oxygen is chiefly required in the free or uncombined state in which it occurs in the air and is taken in by the lungs. The other three are supplied in food, chiefly in the form of proteins, fats, and carbo-hydrates. On chemical analysis, foods are found to consist of certain proximate principles—viz., water, nitrogenous compounds, fats, carbo-hydrates, crude fibre, and salts, thus:

- Foodstuff.
  - Water.
  - Solids.
    - Nitrogenous substances.
    - Non-nitrogenous substances.
      - Fats.
      - Carbo-hydrates.
      - Crude fibre.
      - Salts.

Of these, the first requires little mention here except to say that, whilst **water** adds to the weight of the foodstuff, it adds nothing to its energy-producing value. The **salts**—often called the mineral matter or ash—supply essential constituents of the body tissues; they assist in the processes of digestion; and some of them, such as the phosphates and the lime salts, are especially useful in young growing animals for the formation of bone, but they do not give rise to the production of energy in the body, and for this reason are not included in the so-called "nutrients" of a food.

The "**crude fibre**" consisting of cellulose and its various modifications, such as lignin, is not only largely useless itself as a food for horses, but since it encloses

and prevents the digestion to a greater or lesser extent of other soluble constituents, the digestibility of a foodstuff by the horse may be said to vary inversely as the amount of crude fibre present. Most of the herbivorous domesticated animals can digest a considerable part of the soft fibre of green plants, but only ruminants (ox, sheep, and goat) are able to extract any nourishment from the hard, woody fibre of foods like straw and the coarser leguminous plants.

The **nitrogenous constituents** of a food occur in one of two forms, either as proteins or as amides. The **proteins**, albuminoids, or, as they are often called, flesh-formers, are essential constituents of a diet, because, besides being broken down in the body so as to give up heat or energy, they are the only constituents of food which can build up and repair the muscular tissue which has been subjected to the wear and tear of work. After digestion these bodies are assimilated—*i.e.*, they are incorporated into the proteid tissues of the body.

When a working animal is neither gaining nor losing weight, protein is being assimilated to the same extent as the proteid tissues have been broken down by wear and tear, and this is the minimum amount of albuminoid matter that must be supplied in the food. When broken down in the body by combination with oxygen, proteid tissue is not oxidised to its simplest form, but splits into several bodies, the ultimate products of which are carbon dioxide, water, and urea. **Urea** is an incompletely oxidised constituent of the urine eliminated from the blood by the liver and kidneys, and it contains practically all the nitrogen taken in as food. The amount of urea excreted is therefore an index to the amount of proteid decomposition which has taken place in the body,

and so indicates the quantity of digestible protein which the food must contain.

The **amides** in food are much simpler bodies than proteins $\left(e.g., \text{ urea itself is an amide: } CO<\begin{matrix}NH_2\\NH_2\end{matrix}\right)$, and they can on oxidation give rise to a certain amount of heat or energy, but in the horse have no power of re-building or repairing waste in muscular tissue. Amides chiefly occur in unripe, immature plants, and it is of some importance that the percentage of the nitrogenous matter existing in this form should be stated when the chemical analysis of such a food is given. In ripe foods, such as cereal grains and concentrated foods, amides are present in small quantities only, and are practically negligible.

Of the other proximate principles in a food, the **carbo-hydrates**, consisting of starches, sugars, and soluble cellulose, are made up of carbon, hydrogen, and oxygen. They supply heat and energy on being broken down in the body, and, if given in excess of working requirements, are deposited in the form of fat.

The **fats**, also made up of the same three elements, carbon, hydrogen, and oxygen, require much more oxidising to split them up into their ultimate products —carbon dioxide and water—and, therefore, give rise to a proportionately greater amount of heat and energy than carbo-hydrates.

Both fats and carbo-hydrates are excreted chiefly by the lungs in the form of carbon dioxide (CO_2) and water vapour (H_2O), and are completely oxidised, so that the whole of their potential energy is given up to the body.

Thus, in feeding an adult working horse the diet must be so arranged as to supply—

(1) The actual loss of tissue due to wear and tear of the body, looked upon as a machine.

(2) Material corresponding to the fuel supplied to an engine for the production of energy.

Under (1), the chief loss is in the muscles and other nitrogenous tissues, and must be made good by an equivalent amount of protein.

For (2), is required sufficient fat and carbohydrate, with or without protein for: (a) *maintenance—i.e.*, body heat, energy to carry on the vital processes—circulation, respiration, digestion, secretion, etc.; and (β) the *production* of useful external work.

This must be done with the least waste and at the lowest cost; and in order to secure this economy it is obvious that the various constituents of the food must be supplied in such proportions as are suitable to the animal and its special requirements—in other words, the constituents of the food must be properly balanced.

In the following pages an attempt is made to show what data are necessary for arranging rations for horses, and how, by a careful study of the animal's needs, the cost of the different foodstuffs, and their nutritive values, the best results may be obtained at minimum cost.

CHAPTER II.

THE CHEMICAL COMPOSITION OF FOODS.

The animal body, though containing many complex compounds, is found on analysis into its simplest components to be made up of the following elements: carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, sodium, calcium, magnesium, chlorine, silicon, and iron, with traces of others. Throughout life the body is constantly being built up by means of food, and as constantly worn away by work. It has been said that the body of a man is completely changed every seven years, so that no part of what constitutes the living body to-day will be in the body in seven years' time, but all will have been worn away and replaced by material derived from the food. It is obvious, then, that food must contain all the elements enumerated above, in a form capable of assimilation and elaboration, using the term food to include the air an animal breathes and the water it drinks, as well as the solids eaten.

All the higher animals depend for their food on plant life, and the elements found in the animal body, or simple combinations of them, are abstracted from the air, water, and soil, by growing plants, and built up into the plant substance in such forms as are able to be assimilated by animals. This building-up process carried on by plants requires a considerable amount

of energy, which is supplied by the rays of the sun, and becomes latent or dormant in the components of the plant tissue, and ready to supply the energy needed by the animal. An animal is quite incapable of directly using this solar energy, or of deriving nutrition from simple inorganic compounds, and so is absolutely dependent on the chemical activities of plants. To take one example, the element which forms the largest amount of the dry matter of both plants and animals is carbon, familiar in the impure forms of wood and bone charcoal. In the air there is a practically unlimited supply of carbon, existing as carbon dioxide, a gaseous compound of carbon and oxygen. Normally, the atmosphere contains 4 parts of carbon dioxide in 10,000, and since the atmosphere weighs approximately 14 pounds to the square inch, it follows that there is in the air above us something like 16 tons of carbon dioxide, or 4½ tons of carbon, to the acre. All this is quite unavailable for animals—in fact, carbon dioxide, if concentrated much above the percentage present in air, is a narcotic poison to animals. Plants, however, can take up this gas, and from it assimilate the carbon into the plant cells and tissues—not indeed in the form of the element carbon, but as an organic compound, such as starch or sugar, of a more complex chemical nature than the simple carbon dioxide which the plant took in. Thus the energy of the sun, directed by the vital activity of the plant, has formed from the inorganic simple compound carbon dioxide, by combination with water, a complex organic substance, such as starch, or sugar, or some other member of the important group of food substances known as carbo-hydrates. Carbohydrates are one of the chief sources whence an animal

derives its supply of carbon; in other words, the plant's elaboration of carbon has raised it to a form in which it is available as food for one of the higher animals.

Just as the carbon required by an animal is largely taken in as carbo-hydrate, so the other elements are found to occur in plants in certain combinations suitable for assimilation by animals. On analysis plants can be resolved into these various compounds; and since this resolution is something far short of ultimate separation of the elements, the resulting compounds are termed the **proximate principles** of the plant. They are: water, nitrogenous substances, fats, carbo-hydrates, crude fibre, and salts, and all the foods to be considered later can be resolved into these proximate principles.

Water is present in all foodstuffs, varying in amount from some 12 per cent. in cereal grains to over 90 per cent. in turnips. It is of great importance in the nutrition of an animal that it shall be plentifully supplied with water, but a small amount of water in the food can be made good by a larger quantity of drinking water; and for many purposes concentrated foods, containing little water, are of greater value than the watery, and therefore bulky, green foods or roots. Especially is this so in the case of the working horse, with his small stomach and at the same time large requirements of energy.

The **Nitrogenous Substances** are of two classes, known as proteins and amides, the latter being a stage in the building up, and conversely in the decomposition, of proteins. **Proteins**, albuminoids, or flesh-formers, are composed of the elements carbon, hydrogen, oxygen and nitrogen, with small traces of sulphur and phosphorus, and they are found in protoplasm, the essential vital

substance of the cells of which plants and animals are made up.

The percentage composition of protein may be roughly represented as—

	Per Cent.
Carbon	52
Hydrogen	7
Nitrogen	16
Oxygen	22·5
Sulphur	1·2
Phosphorus	0·45

Thus the element nitrogen forms about 16 per cent. of protein material; and since in an animal whose weight is remaining constant practically all the nitrogen is excreted in the urine, it is easy to estimate the amount of protein assimilated. Most of the work done in and by the body is due to muscular action, and each contraction of a muscle means the oxidation or breakdown of some of its substance, so setting free energy. Now, muscle is made up of a collection of cells, each consisting chiefly of protein. These cells are bathed by the fluids from the blood containing the food materials, protein, sugar, and fat, together with oxygen from the air, and the cells have the vital power of attaching these substances to themselves in more or less stable combination. The object for which the muscle exists is work or contraction, and this requires a supply of energy in the form of food. At each contraction, then, the loosely attached food substances in the muscle cells are broken down by the oxygen, give up their supply of energy, and are resolved into waste products, which are removed from the body. Protein, sugar, and fat, can all act in this way, and, in fact, the latter two serve only this purpose. Protein, however, has a dual rôle, for with

repeated contraction and continued work the muscle tissue, itself protein, gets worn away, and more protein has to be extracted from the food to be actually built up into the muscle tissue. In other words, protein, sugar, and fat from the food can all act as fuel for the muscle engine, but only protein can be used to repair and rebuild worn parts. Thus the body demands a certain amount of protein, which amount is replaceable by no other food substances. Moreover, in a young growing animal, where muscle formation is rapidly going on, the proportion of protein to the whole diet needs to be much greater than at any other time. Similarly, horses doing the fastest work with the greatest taxing of the muscles require a higher proportion of protein than those on slow work. For these reasons, proteins are the most important, but, at the same time, the most costly constituents of a diet.

The **Amides** are generally incapable of rebuilding muscular tissue, but act as heat-producers, and are therefore in line with the other foods—carbo-hydrates and fats—in that they supply a certain amount of energy after assimilation. They are made up of the four elements, carbon, hydrogen, oxygen, and nitrogen, but differ from proteins in that they contain no sulphur or phosphorus, and that their constituent elements are united in simpler combination than in the proteins. Amides are formed in the plant substance as a stage in the manufacture of proteins from simpler inorganic substances. Thus young growing plants contain a larger proportion of their nitrogenous matter in the form of amides than mature ripe plants, a fact well illustrated by the following analyses of hay. These further show the importance, in an accurate calculation of the nutritive value of certain foods, of estimating the nitrogenous

matter under the two separate forms of proteins and amides, and not simply as a joint total:

Percentage Composition of Pasture Grass cut at Different Dates—in 100 Parts of the Dry Matter (Warrington).

Date of Cutting.	Proteins.	Amides.	Fats.	Carbo-hydrates.	Fibre.	Ash.
May 14th	11·5	6·2	3·2	40·8	23	15·3
June 26th	7·8	0·7	2·7	43·3	38·2	7·3

The cereal grains and most concentrated foods fed to working horses contain a very small proportion of nitrogenous substance in the form of amides, so that for practical purposes it suffices to reckon the total nitrogenous matter as equivalent to that amount of protein. In immature and watery foods, such as young grass and roots, in malt-coombs, and, among other foodstuffs, in molasses, the percentage of amides is considerable, and must be allowed for. They must be deducted from the total nitrogenous matter so as to leave only the true proteins, but they should be added on to the other nutrients as energy producers.

The **Carbo-hydrates** in foodstuffs can be divided into two groups—the soluble, such as starch, sugar, and soluble cellulose; and the insoluble, chiefly occurring in the crude fibre as cellulose derivatives, such as lignin. The soluble carbo-hydrates are very important constituents of a diet, and are composed of the elements carbon, hydrogen, and oxygen, the hydrogen and oxygen always being in the atomic proportion of two of the former to one of the latter. A sugar such as glucose,

on being oxidised (*i.e.*, combining with the oxygen taken in by the lungs and circulated all over the system by the blood), is broken down into carbon dioxide and water, and in the process gives up to the body a considerable amount of heat. This is available for keeping the body warm, and also for any internal or external work the animal has to do. If given in excess of the requirements for work, the carbo-hydrates are retained in the body and deposited in the form of fat, this store of energy being available in case of a subsequent shortage of food.

There are many members of the soluble carbo-hydrate class in vegetable foods, and these differ considerably in their feeding value. Much the most important is starch, occurring largely in the cereal grains, and in roots and tubers like potatoes. Starch is present, not in solution in the sap, but in the form of small grains in the vegetable cells, and the starch grains of different plants show definite characters as to size and shape, so that by this means adulteration of a flour can be detected.

Starch itself is insoluble in cold water, but when boiled the starch grains burst, and a viscid, mucilaginous mass is formed, not really a solution. Thus, starch as such, being a member of the class of substances known as *colloids*, is incapable of being assimilated, and it is only when the digestive processes have acted on it and converted it into a soluble substance that it can be absorbed and used in the body. By the action of a dilute acid, or such a ferment as the *ptyalin* of the saliva, starch is first made soluble and then converted into the gum-like substance *dextrin*; whilst, if the process is carried further, a soluble sugar—*maltose*—is the result. Thus there is an intimate relation between starch and sugar, and it is in the form of sugar that the store of

starch in a seed-grain or tuber is transported to other parts of the plant where food is needed. Maltose is an unimportant member of the sugar group in foodstuffs, but it is probably this form into which starch is changed and transferred to the growing sprouts of a germinating seed; and the process of *malting* consists in allowing barley grains to germinate to such an extent that a large amount of maltose is produced. More important sugars are cane-sugar, or saccharose, found in large amount in the sugar-cane and sugar-beet; glucose, dextrose, or grape-sugar, occurring in various fruits; and lævulose, found in honey and fruits, often along with glucose. Another important carbo-hydrate is cellulose, which forms the cell-wall or envelope, inside which the food substance of plants is stored. In order that the cell contents may be made use of, the cellulose envelope must first be broken down or digested, and the power to do this varies greatly in different animals. In the older more fibrous parts of plants the cellulose becomes harder and less capable of digestion, or is actually converted into woody fibre, or lignin, which is practically insoluble. Other less important carbo-hydrates are the gums and pectin bodies, which occur in plants in small amounts; but for feeding purposes they are practically negligible.

The **Fats** and **Oils** are chiefly in the forms of olein and palmitin, compounds of fatty acids (oleic and palmitic), with glycerine. They are composed of the same elements as the carbo-hydrates—namely, carbon, hydrogen, and oxygen; but they require much more oxidation (*i.e.*, will combine with a much larger quantity of oxygen) to break them down into their ultimate products in the body—carbon dioxide and water. For this reason, and in this proportion, they are better

heat-producers than carbo-hydrates, and are therefore extremely valuable for the production of energy or work. Any excess over that used in producing heat or work is stored in the form of animal fat, and so is available in case of a subsequent shortage of food. The fats are present in largest amount in such seeds as soya-beans, cotton-seed, and linseed, also to a less extent in the cereal grains, like oats and barley, and occur even in the straw crops and roots in small amount.

Oxidation.—Before considering the remaining proximate principles, it is necessary to explain as clearly as possible what is meant by oxidation. Many of the vegetable oils or fats are used in commerce for the purposes of heating or lighting, and the main features of the reaction are so familiar as to serve to illustrate the oxidation of food substances in the body. The process of combustion or burning is really a common example of chemical action taking place between two bodies, one of which is oxygen. During the process heat is generated, as in the oxidation or burning of coal and wood, and at the end of the reaction, in place of the original substances, there are left several new substances, in the ashes, as gases in the smoke, and in the soot. Oxidation or combustion may take place suddenly, as in an explosion ; or more slowly in an ordinary fire in which, however, the production of heat is quite evident ; or still more slowly and quietly, as in the union of the food substances in the blood-stream with the oxygen taken in by breathing. A point of great importance, however, is that whether the combustion be instantaneous, as in an explosion, or slow and free from violence, as in the body, whenever the same quantities of the same substances are completely saturated with or united with

oxygen, the action gives rise to the same (total) amount of heat, and to the same new substances or compounds. Thus, whether 1 ounce of fat (tallow) is burned in the form of a candle, or absorbed from the digestive tract of an animal into the blood-stream and oxidised there by the inspired oxygen present in the blood, the total amount of heat produced is the same, and the same compounds, carbon dioxide and water, result. The greater the amount of oxygen required to completely burn up or oxidise a substance, the more heat is produced; and it is because fats require more oxidising than carbo-hydrates that fats supply more heat to the body than the same weight of carbo-hydrates.

The **Crude Fibre** is that part of the food which is of a more or less woody nature, and consists chiefly of cellulose derivatives, such as lignin and cutin. It is found chiefly in the husks of seeds and woody stems of plants, and a large part of it is quite incapable of digestion by the horse. Cattle and sheep are able to digest a much larger proportion of the crude fibre in the foods supplied to them, and thus can make good use of such fibrous materials as oat-straw and undecorticated cotton-cake. The horse, however, with his limited ability to digest crude fibre, would actually starve on food which would nourish an ox. Of the total substance included under the term "crude fibre," there is, then, a digestible and an indigestible portion, and the former appears to have a nutritive value similar to that of starch. Thus, in a food such as wheat-straw, containing about 40 per cent. of crude fibre, of which something like one-seventh is digested, it would appear as though 6 pounds of digested cellulose, with a nutritive value equal to that of starch, should be added to the value of the food. As a matter

of fact, such is not the case, for the work expended in chewing, churning, propelling, and digesting such a coarse food as wheat-straw is greater than that supplied by its digestible constituents, and, *fed alone* to a horse, it is insufficient, in any quantity that the animal can eat, to maintain the animal even at rest. In order, then, to arrive at the real value of the crude fibre in a ration, an adjustment has to be made between the benefit derived from the digestible portion and the loss of energy incurred in dealing with the indigestible woody portion. Thus in practice it may be said that the "crude fibre" in a food is of comparatively little *nutritive* (as apart from its mechanical mass) value to a *working* horse. At the same time, the fibrous part of a food has an important function in supplying bulk in the intestines, and in the case of some foods deficient in fibre, such as maize, a more fibrous material, like timothy hay, has to be fed along with them to allow of a proper movement of the ingesta along the bowel. Thus, whilst an excess of crude fibre in a ration is innutritious, and may even actually lessen the value to the animal of the other nutritive constituents, a certain amount is valuable and necessary. Sometimes the crude fibre of plants may exist in the form of hairs or wool-like fibres, and these may be dangerous, if in large amount, by tending to clump or felt together, so forming concretions or calculi in the intestine—*e.g.*, as in undecorticated cotton-cake. In buying food substances an analysis revealing a high percentage of fibre would suggest a food of low value and correspondingly low price, for some more concentrated, less fibrous, and more expensive food-stuff would be required to bring it up to the standard for a horse.

2

The **Salts**, or **Ash**, are the mineral or inorganic substances in a food, and consist chiefly of simple compounds of sodium, potassium, magnesium, and calcium, with chlorine, carbonic acid, phosphorus, and sulphur. The ash is sometimes called the incombustible part of a foodstuff, in that it is indeed the ash left over after burning the food. The salts do not combine with oxygen in the body, but are excreted in the urine, often in the same form in which they were taken in as part of the food. They therefore supply no heat to the body, and in a certain sense have no nutritive value. At the same time they are essential constituents of a diet, for, as we have seen, the elements of which they are composed are also found in the body tissues, are used up in the chemical activities of the tissues, and therefore must be replaced by salts taken in with food or water. Especially for digestion are salts necessary, as is evident when it is remembered that the gastric juice contains hydrochloric acid, of which the supply must be renewed by the taking in of chlorides, such as sodium chloride (common salt). Again, digestion in the duodenum can only go on in an alkaline medium, due to the presence of sodium carbonate. The blood also can only carry off the waste product, carbon dioxide, as long as it is alkaline from the presence of sodium carbonate. Further, bones, and most of all the tissues, require mineral matter in the food, to the greatest extent during growth, but also throughout life, for the purposes of making good wear and tear. Thus a suitable amount of calcium salts (lime) and phosphates must be present in the food, particularly for young growing animals.

Whilst it is beyond the scope of this work to enter into the details of the chemical analysis of foods, it may

be well to indicate very briefly the methods by which the relative proportions of the proximate principles of a food are determined.

1. **Water.**—A known weight of the substance is taken and dried in a water oven for several hours at 100° C until it ceases to lose weight. The loss in weight represents the water which has been evaporated off, and its proportion of the whole weight of substance originally taken can be easily stated as a percentage. The residue is the dry substance.

2. **Nitrogenous Matter.**—This is estimated in various ways, of which the following method is one. A known weight of the dried substance is mixed with strong sulphuric acid, placed in a flask, and heated. By this means the whole, or practically the whole, of the nitrogen is driven off in the form of ammonia (Kjeldahl's method). Now, proteins contain from 15 to 18 per cent. of nitrogen, or on an average 16 per cent., so that, by multiplying the amount of nitrogen by $\frac{100}{16}$, or 6·25, the amount of protein is arrived at. Since the protein nitrogen content varies, this method would not be accurate under any circumstances, and it is, further, unsound in that it takes no count of the existence of **amides**. However, it sufficiently indicates the procedure followed. To separate proteins from amides it is necessary to precipitate the proteins by means of metallic salts, such as mercuric chloride, or copper sulphate, or by tannic acid. The amides are not affected by these substances, and remain in solution.

3. **Fats.**—The finely powdered and dried substance is subjected to the solvent action of either petroleum spirit or ether, which dissolves out the fats and oils, together with small amounts of waxes, resins, and colouring

matter, such as chlorophyl. Only the fixed fats and oils are of any value as food, so that the ether extract does not strictly represent the nutritive value from the point of view of fat content, but is slightly in excess of the true value.

4. The **Carbo-hydrates**, or "**Nitrogen-free Extract,**" may be obtained by treating a known weight of the powdered foodstuff with dilute (1 per cent.) hydrochloric acid and warming the mixture over the water-bath for some hours. This converts some of the starch into sugar, some only into dextrin. The dextrin has to be treated with rather stronger acid, and the mixture boiled for three or four hours, when the whole of the soluble carbohydrates may be considered to have been converted into (glucose) sugar, which can be estimated.

The more usual method of determining the percentage of carbo-hydrates is by difference—*i.e.*, by subtraction of the total of other components from 100.

5. **Crude Fibre.**—To determine the crude fibre, a known weight of the powdered sample is boiled in dilute sulphuric acid for half an hour, the residue filtered off and boiled in dilute caustic potash solution. The residue is then washed, dried, and weighed ($=W_1$), then ignited, and the ash weighed ($=W_2$). Then $W_1-W_2=$ crude fibre.

6. The **Ash**, or **Mineral Matter**, is obtained by heating the dried foodstuff to redness in a platinum crucible, continuing the heating until the residue is white, then cooling and weighing.

Variation in Composition of Foodstuffs.

In speaking of the chemical composition of a natural foodstuff, it is to be remembered that this is never exactly

the same for any two samples, so that only an average composition can be stated. The composition varies with the many variations in the conditions of growth and preparation of the material. The crop in a wet season has a different composition to that in a dry one, and this is true for every variety of weather and climate. Good land, well manured, will produce a crop very different from that obtained from poor, worked-out soil. Again, as has been already pointed out, the time of harvesting and the degree of ripeness of the crop will materially affect the analysis. Grass in flower and before the seeds are ripe is a very different substance from over-ripe grass with many of the seeds blown away. The stems have become more woody and fibrous and much less digestible. Then, too, the method of harvesting affects the composition. Hay got in fine weather with little handling is vastly better than that left lying, or often turned and spread, in wet, dull weather. Fermentation or heating in the stack further alters the composition, and similarly the harvesting and storage of grains affects their feeding value.

In the calculations throughout this book it is assumed that the sample is a good, unadulterated one, properly harvested and stored, and above rather than below the average sample on the market. It cannot be too strongly impressed on those responsible for feeding horses that the only true economy consists in buying the best quality of foodstuffs. The horse is a particular, and even dainty, feeder, and, further, his digestive powers are such that he is unable to make the best of rough, coarse fodder on which the less particular ruminant would thrive. A poor sample of a foodstuff contains less nutritive material, and that in a less digestible form, than a

good sample. Probably, the animal will eat less of it and waste more, and, in short, such food, although it may be cheap to buy, is in practice uneconomical and extravagant.

TABLE I.

Chemical Composition of Foods.

	Water.	Protein.	Fat.	Nitrogen-Free Extract, or Carbohydrates.	Crude Fibre.	Salts or Ash.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Oats	12·8	11·1	5·1	58·0	10.0	3·0
Maize ...	11·6	10·4	5·1	69·5	1·9	1·5
Beans ...	13·3	25·8	1·3	49·0	7·1	3·5
Peas	14·3	21·9	1·5	54·4	5·0	2·9
Gram	11·4	19·3	3·9	54·2	8·0	3·2
Wheat ...	12·4	11·9	2·0	69·9	1·9	1·9
Barley ...	13·2	11·7	2·1	65·8	4·7	2·5
Rye	13·4	11·0	1·7	70·0	1·9	2·0
Broad bran ...	13·0	14·6	4·0	53·8	8·8	5·8
Brewers' dried grains ...	8·9	20·6	6·7	43·6	15·9	4·3
Meadow hay (best) ...	15·0	11·3	2·8	41·2	23·1	6·5
Clover hay (medium) ...	16·1	12·7	2·7	37·5	25·3	5·9
Sainfoin hay ...	16·5	13·2	2·5	32·5	28·0	7·3
Oat straw ...	14·0	3·9	2·0	37·7	36·9	5·5
Wheat straw	13·5	3·2	1·3	39·6	37·7	4·7
Carrots ...	87·3	1·2	0·3	9·0	1·3	1·0
Pasture grass	80·0	3·5	0·8	9·7	4·0	2·0
Vetches ...	82·0	2·4	0·6	8·6	5·1	1·3
Lucerne (green)	76·0	4·1	0·8	9·3	7·6	2 2

CHAPTER III.

DIGESTION AND DIGESTIBILITY.

On examining any ordinary foodstuff in the dry state, it is evident that many changes must take place before, from this rough, dry, insoluble material, soluble nutritive substances can get through the intestinal wall into the blood-stream to feed all the tissues of the body. These several changes constitute the process of digestion. It will be easily understood that different foodstuffs will require different treatment, in order that all their useful food material may be extracted from them; and it is common experience, alike in man and animals, that one food is more digestible than another. Thus it is necessary in appraising the value of any one food to know to what extent the nutritive substances it contains are digested, for it is not the amount of food ingested, but the amount digested, which really gives nutriment to the animal.

When a food is taken into the mouth, it is first masticated or broken up by the grinding teeth, mixed with saliva, and then swallowed. Mastication is important in that it allows thorough penetration of the digestive juices to all parts of the food, and especially is this necessary in the case of grains covered with a fibrous envelope or husk, itself but little digested. In the mouth, then, the food-mass is ground down into small particles and saturated

with saliva, which begins the process of digestion by attacking the starches and converting them into sugar, which can be absorbed. This action of the saliva continues for some time after the food has reached the stomach, but gradually the stomach wall pours out the active digestive gastric juice. This attacks especially the proteins, breaking down their complex molecules into the smaller and simpler peptones, which can be absorbed through the intestinal wall and taken up into the bloodstream. After a variable time—three to four hours—the food-mass, now in the form of a semi-liquid paste, is passed on from the stomach into the small intestine, and here it comes in contact with the bile and pancreatic juice. These digestive secretions further break down the compounds presented to them, the bile especially attacking the fats and causing them to assume the form of minute droplets, and the pancreatic juice acting on any starches not yet converted into sugar, on any proteins not yet changed into peptones, and on the fat droplets, to form a soluble compound which can be absorbed. Now, the intestinal wall has ramifying in it very numerous fine capillary blood vessels and lymphatics, and when the digestive juices have acted on the food in the manner described, the newly formed sugars, peptones, and soluble fatty compounds (soaps) are in close contact with the blood and lymph in these vessels, so that it is easy for them to pass through, get into the blood, and become available for the food needs of the animal. This is the process of absorption, which is especially active throughout the small intestine and, to a less degree, in the large bowel. The unabsorbed part of the food is propelled along the small intestine by its muscular wall and reaches the large intestine. Here the chief digestive

process is that whereby cellulose and fibre are broken down and made soluble, largely as a result of the action of the immense numbers of bacteria which this part of the bowel contains. In cattle, sheep, and goats (ruminants), the digestion of cellulose is much more efficient than in the horse, and, moreover, it takes place in the first stomach, or rumen. The consequence is that the fibrous cell walls, husks, and stems, are broken down and their contents set free *before* true stomach and small intestine digestion have taken place, and so no starches, proteins, and fats, are allowed to escape digestion because of being enveloped in a protecting layer of cellulose. In the horse, on the other hand, cellulose digestion occurs *after* stomach and small intestine digestion, and thus it happens that a woody or fibrous envelope often prevents nutritive starches, sugars, proteins, and fats, from being acted on by the digestive juices, and these nutrient substances are passed out as waste material with the excreta. Thus the presence of a large percentage of cellulose or woody fibre in any food material renders it unsuitable for horses; for, even though it may show a good chemical composition on analysis, the animal is unable to digest a large part of the fibrous cell walls, and, hence, much of the nutritive material passes out unchanged and unused.

It must not be supposed that a food with no cellulose or fibre would be suitable for the horse, for the fibre adds bulk to the food, and there is an intimate relation between the capacity of the intestines and the required bulk of food. The bowel must be sufficiently full, because the passage of material along the tube depends upon muscular contraction, which is only set up by the contact of a certain bulk of food on the sensitive lining

of the wall. Further, moderate distention is necessary for the stimulation of the mucous membrane to secrete enough fluid to liquefy the ingesta. In rabbits fed upon flour only, a kind of inflammation is set up by the stoppage of the food in the intestine, and the animals soon die. Similarly, horses fed on maize, a food containing very little fibre, require some rough, hard hay—such as timothy or cocksfoot—or even a little oat-straw, for otherwise the intestines become filled with a pasty or putty-like mass, which cannot be propelled along the bowel, and colic and fatal impaction soon occur. It has been estimated that whilst the capacity of the digestive tract of the horse is about 46 gallons, that of the ox is about 78 gallons, and these figures give some guidance as to the relative bulk of food to be supplied to the two animals.

The attempt to determine what percentage of a food is digested by an animal may be made in one of two ways. Firstly, the method of artificial digestion may be tried by submitting a finely ground sample of the food to the action of the salivary, gastric, and pancreatic juices respectively, in a glass vessel kept at the body temperature. Digestion does, in fact, go on, and some of the starches and proteins are converted into sugar and peptone respectively, but the conditions are so artificial that the results are quite inapplicable to an animal. Again, as has been shown, there is a great difference in the digestive powers of the horse and ox, so far as crude fibre is concerned, and this is true, only to a less degree, of the other constituents of food. In other words, the digestibility of the same food is different with different species of animal, and in each must be determined separately.

The second, and only useful, method, then, is to determine the digestibility of the food in the particular animal desired by giving a known weight of the food, and then collecting and estimating the amount of undigested waste matter in the excreta. To find the digestibility of a particular food for the horse, the procedure consists in giving the food for several days before commencing records of the experiment, in order that the digestive tract may be emptied of all but that food when the collection and estimation of the excreta commences. After this, for six or seven days the animal receives daily a known weight of the food, and by means of a specially arranged bucket all the dung is caught. The droppings for the day are all mixed together, and a certain weight is taken for analysis.

Knowing the chemical composition and weight of the food supplied, and also the chemical composition and weight of the excreta, it is easily seen, by difference, how much of the food was digested and absorbed for every 100 parts supplied. As stated above, the carbo-hydrates, proteins, and fats, in a food have to undergo different changes in the digestive tract before they can be absorbed, so that it is not surprising to find that even in the same food these nutrients are digested to quite different extents. In one food the fats may be in a very digestible form, whilst the proteins are digested only with difficulty and to a small extent; in another food the reverse may be the case. Thus it is necessary to determine by experiment with each food what proportion of each of its nutritive components is digested by the animal in question—in this case the horse. In the case of a food which it is impossible or inconvenient to give alone (such as any of the straws), it is fed along with some

other food of known composition and digestibility, and the proper deductions made in estimating the excreta. An even more exact determination of the digestibility of a food can be made by means of an apparatus known as a "respiration chamber," in which the animal is placed during the course of the feeding experiment, so that not only the urine and fæces can be obtained for analysis, but the intake of oxygen and output of carbon dioxide by the lungs can also be determined. By this means a complete record of the animal's intake of food and excretion of undigested and waste products is obtained; and, further, the method is of great value in determining the use of food in relation to work. For the purposes of this book the results of the digestion experiments carried out by Wolff, Kellner, Zuntz, and other German workers, have been entensively used, though some figures are taken from Jordan and Hall's compilation published by the United States Bureau of Animal Industry. Out of 100 parts of a food supplied, the number of parts digested is stated, and this number is called the *digestion coefficient* of that particular food. Of course, these figures refer to the digestion of a good sample of the food by a horse in normal health and under normal conditions.

There are circumstances which altogether alter the digestibility of a food, and some of these must be mentioned now. The quality of the food itself is undoubtedly a factor, for just as quality affects the chemical composition, so it affects the digestibility. Bad as a poor sample of food may be shown to be by analysis, it may be, in fact, much worse in the animal because of lowered digestibility. Especially in the horse does excess of crude fibre lower the digestion coefficients. Again, a food

must be palatable and appetising for the digestion to be at a maximum, so that mouldy or dirty fodder, even when mixed in small amounts with sound fodder, lessens the digestibility of the whole.

Another factor affecting digestion is the combination of foods supplied in the ration. For example, an excess of starchy matter relatively to protein and fats will depress the digestibility of the whole ration, so that if to a fairly balanced ration 2 lbs. of dry starch be added, it will be found that less protein and less fat are being digested than before. Thus the addition of a food like potatoes to a diet poor in protein would further depress the digestibility of each component of the whole ration. If, however, a further addition of protein material were now made, this would improve the digestibility for each ingredient. Thus it has been demonstrated that any excess of carbo-hydrate over about 10 parts to 1 of protein means that some of the digestible part of the ration fails to be digested, and is passed out with the excreta. Digestion is also affected by the total quantity of food supplied. A large ration, in excess of the requirements of the animal, is not digested to the same extent as a smaller one sufficient for the animal's needs; and the greater the excess, the more is digestion depressed. Thus overfeeding is extravagant, because the excess over the requirements is not serving any useful purpose, and also because, of the food supplied, a smaller proportion is being absorbed and used in the overfed animal than in one just sufficiently fed. For digestion to be satisfactory it is necessary for the horse to have a certain number of hours at rest in the stable. Experiments seem to show that ordinary work has little detrimental effect on digestion, but fast work does interfere with it. This is in agreement with practical

experience that heavy, slowly worked horses can be worked longer hours than the lighter, faster breeds. At the same time, a horse is no more able to burn the candle at both ends with impunity than a man.

Water plays a very important part in connection with all the vital processes, and not least in connection with digestion. In digestion the food constituents are made soluble, and it is from the solution of foodstuffs in the intestine that the blood draws its supplies. The blood itself soon becomes thicker and too concentrated unless an ample supply of water is taken in. The digestive juices, secreted in large amount in the twenty-four hours, have to be provided for by fresh supplies of water; and the waste products, such as urea, which are eliminated by the kidneys, require an adequate amount of water for their solution and excretion. Thus the digestive tract is constantly being drawn upon for water for the use of the body in all its activities, and yet at the same time the bowels themselves must contain a sufficient amount to keep the ingesta in that fluid condition necessary for easy propulsion along the canal. Too little water means a delay in the passage of the ingesta through the intestine; an increased tendency to impaction or obstruction with dry, bulky material, and consequent colic; and if even the latter is avoided, the whole of the activities of the body are less efficiently carried out. Thus an ample supply of water is of first-rate importance, and there can be no doubt that the best plan, where possible, is to allow the horse access to a constant supply in the stable.

Although somewhat beyond the scope of this book, it is perhaps desirable to point out that in an individual animal supplied with good food, easy of digestion by a normal horse, the whole process may be upset by some

disease or abnormal circumstance. Thus any disease of the teeth will interfere with proper mastication of the food; coarse fodder, such as hay, will be wasted; many grains will escape crushing, and therefore digestion; and if nothing worse happens, the animal will lose condition and be unable to do his work. Again, the presence of parasites—in the form of various worms—in the digestive tract will prevent the digestive processes going on normally, will often cause diarrhœa, and in every case lessen the productive value of the food supplied. Lastly may be mentioned the effects of fatigue and overwork. These bring about a loss of tone in the digestive apparatus, a lessened secretion of the digestive juices, want of power in the bowel wall, and therefore a lessened use of the food materials supplied, together with danger of impaction and other acute bowel diseases. Extreme old age has a similar effect.

Most horse-owners are aware of the prevalence and danger of colic in horses, but not by any means all these recognise that the majority of cases of colic are due to one of two causes—namely (1) excessive work, or (2) bad stable management, chiefly in connection with feeding and watering. The legion of advertisements advocating "condition," "digestive," and "tonic," powders for improving the horse's digestion exist because of the failure of the horse owner to recognise that *a normal digestion requires no improving,* and, moreover, any attempt to improve it by drugs and condiments will result in failure, and possibly in the production of disease. When the horse's digestion is out of order, endeavour should be made to discover the cause, if necessary with the aid of professional advice, and remove it, and then the trouble will cease. Above all, let it be remembered that the effects of a badly-arranged dietary,

poor quality food, overwork, or diseased teeth, will never be got rid of by means of drugs, unless and until the faulty management or the operating cause is got rid of.

The following table gives the "digestion coefficients" —*i.e.*, the percentage amounts digested by the horse of the nutritive principles of the common feeding-stuffs. The figures have been obtained as the result of numerous experiments carried out by the authors mentioned above.

TABLE II.

Digestion Coefficients in the Horse for 100 Parts of Each Material Supplied.

	Protein.	Fat.	Nitrogen-Free Extract, or Carbohydrates.	Crude Fibre.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Oats	81	71	75	27
Maize	77	62	93	70
Beans	86	11	93	66
Peas	85	7	91	8
Gram *	80	10	85	35
Wheat	76	55	90	45
Barley	75	45	87	25
Rye	75	55	80	24
Broad bran ...	78	64	70	20
Brewers' dried grains	75	80	61	30
Meadow hay (best)	62	21	60	46
Clover hay ...	56	29	64	37
Sainfoin hay ...	73	15	70	43
Oat straw... ...	33	36	45	25
Wheat straw ...	28	33	28	18
Carrots	99	—	94	—
Pasture grass ...	70	15	66	57
Vetches	70	55	75	35
Lucerne (green) ...	73	25	67	30

* These coefficients are *assumed* from the composition of gram and its likeness to peas. They have not been experimentally determined.

CHAPTER IV.

ESTIMATION OF THE REAL NUTRITIVE VALUE OF FOODSTUFFS.

It may at once be stated that the **market price** of a foodstuff is by no means a reliable index to its true feeding value. This statement is even truer in relation to the feeding of horses than in feeding cattle and sheep, for the question of the manurial value of the residue of the food does not concern the majority of horse owners. It is necessary, then, to determine the criteria by which to judge of the real value of any foodstuff in order to compare its cost with that of other similar foods for which it might be substituted.

As we have seen, for nutritive purposes the important constituents of a food are the proteins (albuminoids), fats, and carbo-hydrates. Amides and the digestible part of the crude fibre must also be considered nutritive in a limited degree. For maintenance and repair of muscular tissue proteins are indispensable, whilst for the purposes of producing energy and work the other constituents are all useful, but have widely different values. Thus a **chemical analysis** to determine the amount and proportion of these nutrient constituents is the first requirement in estimating the value of any foodstuff (see Table I., p. 22).

Next it is necessary to know the comparative values

that these food elements have in supplying the wants of the animal. The only satisfactory way to estimate this is in terms of their heat-producing power when broken down in the tissues. Proteins, fats, and carbo-hydrates, when fully combined with oxygen, are split up much in the same way that combustible material is burned in a fire, and with a similar result—namely, the production of heat. This heat is capable of conversion into various other forms of energy, such as the muscular energy expended in locomotion; in doing work, as in the case of a draught-horse; in carrying on the vital bodily processes, such as the movements of the heart and respiratory organs; and in the secretion of the juices from the various glands. All these forms of energy can be estimated and stated in terms of heat, and all are provided for by the food and air taken in by the animal. Thus the heat-producing capacity of a food is the real measure of its nutritive and work-producing value. In other words, there is a direct proportion between the amount of heat produced by oxidising or burning the nutritive parts of a food and the amount of energy or labour they will supply after assimilation by a horse or other animal. Many and repeated experiments have been made to ascertain the comparative heat-producing power of the nutritive constituents of food. The principle made use of in these tests is to take a certain amount of the substance under investigation, mix it with an excess of some active oxidising agent, such as potassium chlorate, and place the mixture in a metal case or bomb, provided with electric terminals. The bomb is inserted in a special form of water calorimeter (a heat-measuring instrument), and by means of an electric spark the mixture is fused.

Thus complete oxidation or combustion of the substance is brought about, and the heat given off by a known quantity of it raises the temperature of the water, and so is determined. It is found by this means that equal quantities of fat, protein, and carbo-hydrate, on combustion produce heat in the proportion of 2·3, 1·25, and 1, respectively. Proteid matter really produces more heat than this in a calorimeter, but a deduction has been made equivalent to the heat-producing power of the urea excreted. In practice these comparative heat values are found to be true so far as the maintenance diet of an animal is concerned, but for labour purposes proteid and carbo-hydrate are found to be of similar value, so that the proportion becomes 2·3 : 1 : 1.

It has already been explained (Chapter II.) that amides, although allied to proteins in composition, are unable to build up the nitrogenous tissues of the body, but can supply heat and energy on oxidation. Experiments have determined their heat value to be 0·6 when compared with a value of 1 for starch, so that in a food containing a large percentage of amides this heat value must be added to that of the other heat-forming constituents.

The digestible part of the "crude fibre" is really cellulose, and has a heat value practically the same as starch. From this, however, a deduction has to be made for reasons stated below (p. 36).

But there is another factor of supreme importance to consider before we can really fix the value of a food—namely, its **digestibility**. We have already seen that in the process of digestion, protein, fats, and carbohydrates, are dealt with separately, and in any one food they are digested in quite different proportions. Thus

in one food the protein may be in a form easily digested and assimilated, and of the total protein contained in the food and taken in by the mouth a very high percentage is taken up into the animal economy and made use of. It may be that in the same food the fats and carbo-hydrates are much less digestible, and that of the total present in the food a large proportion is wasted and passed out with the excreta, having added nothing to the animal economy in the way of nutrition or energy. Thus it is necessary to find the percentage of each nutritive constituent digested for every separate food, and for the particular species of animal (horse, ox, sheep, etc.) in question. The digestibility of the nutritive principles of the common feeding-stuffs has been worked out experimentally, as detailed in an earlier chapter (Chapter III.), and it is only necessary to emphasize the necessity of considering this factor in deciding the true nutritive value of any food.

Even after considering the digestibility of the proximate principles of a food, it is found that a comparison between very dissimilar foods cannot well be drawn, for it frequently happens that the digestible constituents of one food are more readily assimilated and utilised in the body than those of another food. This *availability* of the digestible parts of a food largely depends on the amount and kind of the crude fibre present in the food, and the necessary correction may be made by deducting 1 from the figure representing the comparative heat value of that food, for every 3 per cent. (or in the case of the coarse fodders, such as hay and straw, for every 2 per cent.) of crude fibre present in it.*

* This point will be made clearer for practical purposes by studying an example, such as the calculation on p. 40.

One last item remains to be considered before we can fully estimate the value of a foodstuff or ration, and that is the proportion of the various nutritive constituents in it relative to one another—in other words, the **balance** of the food. Since proteins, fats, and carbo-hydrates, have different uses in the body (a certain minimum quantity of proteid matter being essential for repair of waste, whilst the other two, heat and energy producers, are largely interchangeable, so that a deficiency in one can be made good by an increase in the other), it is obvious that an economical diet will require some balance between the nitrogenous and non-nitrogenous constituents. The proteid, or albuminoid part of a diet, is by far the most costly; and although proteins contain the essential elements (carbon, hydrogen, nitrogen, and oxygen) needed to supply the body requirements, it is both practically and economically impossible to feed an animal by giving protein alone. What the body must have is a certain minimum quantity of nitrogenous or proteid matter, and then its further requirements of carbon and hydrogen can be supplied in the form of the less costly fats and carbo-hydrates. Not only is it necessary to have a minimum amount of protein and a proportional amount of fats and carbo-hydrates in the ration for a resting horse, but if any work is required of the animal a proportionate extra quantity of food has to be supplied to provide the necessary energy. At first sight it might appear that any one of the three nutritive constituents of food might be added to the resting diet in sufficient quantity to supply this extra energy; but in practice it is again found that a certain balance must be kept between the proteins, fats, and carbo-hydrates. The balance, or ratio, varies with

different animals, and for different purposes in the same animal, but any other than the optimum nutritve ratio is attended with waste of one or other of the constituents supplied, and is bound to be uneconomical. If this optimum balance is upset, the percentage of each food digested at once alters—*e.g.*, if the percentage of protein in a ration is too low, the digestion of protein per 100 parts supplied in the food falls off, and so the nitrogenous part of the diet, the most costly part, is subject to greater waste. Again, if the quantity of protein supplied is excessive, the appetite for it increases, the animal puts on flesh, and extravagance occurs. To determine the right proportion in which to supply these nutritive elements in food, we may proceed in two ways: (1) by studying this proportion in the natural food of the animal we are considering, and by noting how the ratio varies with the varying circumstances of the animal's life; and (2) by experimentally determining the best balance for any particular animal used for a particular purpose. Since the performing of work is unnatural, we can get little or no information from Nature at all comparable with working conditions, so that the latter method is the better for working rations. In the feeding of young animals—foals and calves—we can use the former method with great advantage by analysing their natural food—namely, milk.

The ratios which we require to know are termed the "**nitrogenous**" and the "**fatty**" ratios, the former being by far the more important. They may be represented thus:

$$\text{Nitrogenous ratio} = \frac{\text{N}}{\text{F} \times 2{\cdot}3 + \text{C.-H.} + \text{D.F.}}$$

$$\text{Fatty ratio} = \frac{\text{F}}{\text{N}}$$

where N, F, and C.-H., and D.F. = the respective amounts of protein, fat, carbo-hydrate, and fibres digested from 100 parts of the food.*

Thus the nitrogenous ratio is a statement of the amount of digestible proteid matter compared with the amount of carbo-hydrate (including digestible fibre) and fat taken together, but since these two have different values in the production of heat and work, they must first be reduced to the same terms—*i.e.*, the fat must be stated in terms of its equivalent of carbo-hydrate. To do this, the amount of digestible fat is multiplied by the factor 2·3.† For the purposes of hard town work—say a trapper in London, or a dray-horse working at a trot—the optimum nitrogenous ratio is found to be 1 : 5·5, or 1 : 6.

The fatty ratio is much less important, and is simply a statement of the amount of digestible fat compared with digestible protein of the food. It is of some advantage that this should be within the limits 1 : 2 to 1 : 3·5 in a ration for a horse at work.

And now we are in a position to ascertain the real value of any particular food. Taking 100 lbs. of the food, its composition is determined by chemical analysis, and the amounts of the contained protein, fats, carbo-hydrates, and crude fibre are written down. Next the percentage of each of these constituents digested by the horse is found from the tables, and the net amount digested calculated out. Lastly, the amount of fat digested is multiplied by the factor 2·3, and then by the addition of the digested protein, carbo-hydrate, crude fibre, and fat

* For the "nitrogenous ratio" of a mixture of foods comprising a ration see p. 57.

† It is, of course, obvious that these ratios are only useful when reckoned on the digestible part of the foodstuff, since the undigested part is of no value to the animal.

$\times 2{\cdot}3$ we arrive at a total representing the comparative heat value of the food in terms of digestible starch.*

The correction for crude fibre must still be made,† so that if the percentage of this in the food under examination is 12, we have to deduct $\frac{12}{3}=4$ from the total representing the comparative heat value. The corrected total now represents the real value of 100 lbs. of the food, and is called the "starch equivalent" of the food. Arrived at in this way, it affords the most practicable means of stating the relative nutritive value of any foodstuff.

Two examples will suffice to make the estimation of the nutritive value of a food quite plain. Oats and hay have been selected as being the commonest foodstuffs supplied to horses.

I. Oats.

	Amount in 100 Lbs.	Percentage Digested.	Amount Digested.	Heat Coefficient.	Heat Value.
Protein ...	11·1	81·0	8·99	1·0	8·99
Fat	5·1	71·0	3·6	2·3	8·28
Carbo-hydrate	58·0	75·0	43·5	1·0	43·5
Crude fibre ...	10·0	27·0	2·7	1·0	2·7
					63·47
‡ Deduct for crude fibre $=\frac{10}{3}=$					3·33
Comparative heat value or "starch equivalent" =					60·14

* For 1 lb. of proteid matter and 1 lb. of carbo-hydrate (starch) are of the same value, and 1 lb. of fat is equivalent to 2·3 lbs. of carbo-hydrate (starch), so that 1 lb. protein + 1 lb. carbo-hydrate + 1 lb. fat = 4·3 lbs. starch.

† See p. 36.

‡ Since oats contain 10 per cent. of crude fibre.

In other words, 100 lbs. of oats fed to a horse is equivalent to 60·14 lbs. of digested starch for the supply of heat or energy.

II. Meadow Hay.

	Amount in 100 Lbs.	Percentage Digested.	Amount Digested.	Heat Coefficient.	Heat Value.
Protein ...	11·3	62·0	7·0	1·0	7·0
Fat	2·8	21·0	0·58	2·3	1·33
Carbo-hydrate	41·2	60·0	24·7	1·0	24·7
Crude fibre ...	23·1	46·0	10·62	1·0	10·62
					43·65
* Deduct for crude fibre $= \frac{23{\cdot}1}{2} =$					11·55
Comparative heat value or "starch equivalent" =					32·1

So that 100 lbs. of meadow hay fed to a horse is euivalent to 32·1 lbs. of digested starch.

The "nitrogenous ratio" of oats is:

$$\frac{\text{N}}{(\text{F} \times 2{\cdot}3) + \text{C.-H.} + \text{D.F.}} = \frac{8{\cdot}99}{(3{\cdot}6 \times 2{\cdot}3) + 43{\cdot}5 + 2{\cdot}7} = \frac{8{\cdot}99}{54{\cdot}48} = \frac{1}{6{\cdot}06};$$

i.e., a ratio of 1 : 6.

The "fatty ratio" of oats is:

$$\frac{\text{F}}{\text{N}} = \frac{3{\cdot}6}{8{\cdot}99} = \frac{1}{2{\cdot}5};$$

i.e., a ratio of 1 : 2·5.

The "nitrogenous ratio" of hay is—

$$\frac{\text{N}}{(\text{F} \times 2{\cdot}3) + \text{C.-H.} + \text{D.F.}} = \frac{7}{(0{\cdot}58 \times 2{\cdot}3) + 24{\cdot}7 + 10{\cdot}62} = \frac{7}{36{\cdot}65} = \frac{1}{5{\cdot}23};$$

i.e., a ratio of 1 : 5·23.

* Since hay contains 23·1 per cent. of crude fibre (see p. 36).

This is a high ratio, due to the fact that hay is deficient in digestible fat. The large amount of crude fibre in hay so adds to its bulk and lessens its "availability" as to quite do away with this apparent value as a highly concentrated food.

The "fatty ratio" of hay is:

$$\frac{F}{N}=\frac{0{\cdot}58}{7}=\frac{1}{12};$$

i.e., a ratio of 1 : 12.

By such an analysis, then, as the foregoing we are enabled to estimate the actual and comparative values of the foodstuffs open to our choice.

UE OF FOODS IN HEAT UNITS OR "STARCH EQUIVALENT."

		Carbo-hydrates or Nitrogen-Free Extract.			Crude Fibre.					
Amount Digested from 100 Lbs.	Value in Terms of Starch (×2·3).	Amount in 100 Lbs.	Digestion Coefficient.	Amount Digested from 100 Lbs. or Value in Terms of Starch.	Amount in 100 Lbs.	Digestion Coefficient.	Amount Digested from 100 Lbs.	Deduction (1 for every 3 Per Cent.)	Net Value of Fibre in Terms of Digestible Starch.	Total Available Heat Units in, or "Starch Equivalent" of, 100 lbs. of the Food.
Lbs.	Lbs.	Lbs.	Per Cent.	Lbs.	Lbs.	Per Cent.	Lbs.	Lbs.	Lbs.	Per Cent.
3·6	8·28	58·0	75·0	43·5	10·0	27·0	2·7	3·33	– 0·63	60·14 (oats)
3·16	7·27	69·5	93·0	64·6	1·9	70·0	1·33	0·63	+ 0·7	80·57 (maize)
0·14	0·32	49·0	93·0	45·5	7·1	66·0	4·68	2·36	+ 2·32	70·32 (beans)
0·1	0·23	54·4	91·0	49·5	5·0	8·0	0·4	1·66	– 1·26	67·07 (peas)
0·39	0·897	54·2	85·0	46·07	8·0	35·0	2·8	2·6	+ 0·2	62·6 (gram)
1·1	2·53	69·9	90·0	62·9	1·9	45·0	0·85	0·63	+ 0·22	74·69 (wheat)
0·94	2·16	65·8	87·0	57·2	4·7	25·0	1·17	1·56	– 0·39	67·67 (barley)
0·935	2·14	70·0	80·0	56·0	1·9	24·0	0·45	0·63	– 0·18	66·21 (rye)
2·56	5·89	53·8	70·0	37·66	8·8	20·0	1·76	2·93	– 1·17	53·76 (bran)
5·36	12·33	43·6	61·0	26·59	15·9	30·0	4·77	5·3	– 0·53	53·84 (dried grains)
0·58	1·33	41·2	60·0	24·7	23·1	46·0	10·62	11·55	– 0·93	32·1 (meadow hay)
0·78	1·79	37·5	64·0	24·0	25·3	37·0	9·36	12·6	– 3·24	29·65 (clover hay)
0·37	0·85	32·5	70·0	22·75	28·0	43·0	12·04	14·0	– 1·96	30·24 (sainfoin hay)
0·72	1·65	37·7	45·0	16·96	36·9	25·0	9·22	18·4	– 9·18	10·71 (oat straw)
0·429	0·98	39·6	28·0	11·08	37·7	18·0	6·78	18·8	– 12·02	0·96 (wheat straw)
—	—	9·0	94·0	8·46	1·3	—	—	0·43	– 0·43	9·21 (carrots)
0·12	0·27	9·7	66·0	6·4	4·0	57·0	2·28	1·33	+ 0·95	10·07 (pasture grass)
0·33	0·76	8·6	75·0	6·45	5·1	35·0	1·78	1·7	+ 0·08	8·97 (vetches)
0·2	0·46	9·3	67·0	6·23	7·6	30·0	2·28	2·53	– 0·25	9·33 (lucerne)

Deduction (1 for every 2 per cent.).

To face p. 42.

CHAPTER V.

MAINTENANCE REQUIREMENTS OF AN ANIMAL AT REST, AND WORKING REQUIREMENTS.

Before deciding what amount of food is required by a horse at any particular kind of work, it is necessary to determine how much food is used up by the body when the animal is doing no external work at all. Even at rest work is being done *in* the body, and this work must be provided for by adequate supplies of food and air. The ordinary petrol motor affords a good illustration of this point. On disconnecting the gearing, the forward or backward movement is stopped, and the conveyance pulled up, although the motor continues to work with expenditure of energy, and petrol continues to be used. Stop the supply of petrol, and the machine stops altogether. In the horse at rest a considerable amount of work is being done: the heart is beating to drive round the blood; the chest muscles are contracting to pump air in and out; the digestive apparatus is at work manufacturing and pouring out the various juices needed to dissolve the useful parts of the food, mixing and moving on the ingested material from stomach to small intestine, and from small intestine to large, finally excreting the waste material; the kidneys are filtering off waste products separated from the useful material by the liver; and over and above all, controlling and co-ordinat-

ing all these, is the brain and nervous system. Now, all these processes require the expenditure of energy, and this has to be supplied by the food. The amount of food required for this purpose is called the *maintenance* diet, and many experiments have been performed in order to determine the suitable quantity. It will be evident that the maintenance ration must be such that the animal loses no weight, and puts on no fat or increase of flesh, but remains in a state of equilibrium. In the case of the horse, the amount of food necessary for a resting animal should be known, for not only is it unnecessary, but it is actually dangerous to health, to feed the same amount to a resting as to a working animal. Now, it is quite possible to *maintain* an animal on one foodstuff alone, if given in suitable quantity; but it is rarely, if ever, economical to do so, for digestion of the various constituents is almost always improved in a mixture properly arranged. Again, in the horse, experimental determination of a maintenance diet is complicated by the fact that the animal during the experimental period needs some exercise, and, of course, this increases the food demand. This circumstance, however, corresponds to the actual conditions when feeding resting horses for any length of time, since they, too, must have exercise.

Taking a horse weighing 1,000 lbs., various estimates have been arrived at, of which the most carefully determined are those by Wolff, Zuntz, Grandeau, and Kellner.

Wolff's estimate is 6·78 lbs. of digestible organic matter, exclusive of digestible crude fibre. Grandeau, experimenting with three cab-horses for fourteen months, came to a very similar conclusion—namely, 6·75 lbs. digestible nutrients per 1,000 lbs. Zuntz, with more

modern methods and great scientific detail, gives the amount required as 6·4 lbs. of digestible nutrients when the total ration contains not more than 3 lbs. of crude fibre, and this limiting of the amount of fibre is one reason why a mixed diet of corn and hay is more economical than one of hay alone. Kellner investigated this question with care in two ways, and his conclusions are of considerable practical value, because they are easy of application. In his first experiment he fed a number of bus-horses on *one-third their working diet*, and, after periods varying from forty to forty-eight days, he found they had lost weight to an average extent of 5 per cent., so proving that the ration was inadequate. He then changed the ration to *half the working scale*, and after from twenty-five to thirty-three days the horses had recovered their former weight, and even exceeded it by an average of 1·5 per cent. Evidently the new ration was too good for maintenance. He then took a fresh lot of working horses, and gave them *five-twelfths of their working diet* whilst keeping them at rest, and this he found to be quite sufficient—in fact, after thirty to forty-eight days they had increased on the average something over 1 per cent. of their weight. Thus Kellner concludes that five-twelfths of a suitable working ration is sufficient for purposes of maintenance. In two other series of experiments Kellner determined the maintenance ration in terms of digestible starch, the quantity required being 3·3 kilos. for horses weighing 500 kilos., or, in other words, nearly 7 lbs. per 1,000 lbs. weight.

Thus we may conclude that for maintenance alone a horse of 1,000 lbs. weight requires an amount of food providing the equivalent of 6½ to 7 lbs. of digestible starch. This must necessarily contain enough protein

to make good the protein wear and tear of the body, and the experiments referred to prove that the minimum amount necessary is something under $\frac{3}{4}$ lb. daily (0·6 to 0·7 lb.). This amount will maintain the animal in the state of nitrogenous equilibrium, the urea excreted in the urine being exactly proportional to the protein given in the food. If less than this amount of protein is given, the urea excreted still remains at the same level—that is to say, more is eliminated than can have come from the food protein, and therefore it must have been formed from the breaking down of the animal's own proteid tissues, and the animal loses weight in consequence. Further, for the food to be digested to the fullest extent, the nitrogenous ratio should not be wider than 1 : 10, or at the outside 1 : 12; otherwise to obtain the necessary protein a large bulk of a poor food has to be given, the digestibility is low, and a considerable part of the nutrients in the food are excreted unused. Thus, while it is perfectly possible to maintain a horse on one foodstuff alone, it is rarely, if ever, economical to do so. The better method is to use a mixed ration, just as in feeding a working animal, but with the wide nitrogenous ratio indicated above, and possessing the necessary value in starch equivalents.

Such a ration is provided by any of the following mixtures:

		Lbs.
1.	Meadow hay ...	10
	Oats ...	5
	Carrots ...	10
2.	Hay ...	10
	Oat straw ...	5
	Oats ...	6

		Lbs.
3.	Hay	10
	Oat straw	5
	Maize	2
	Oats	3
4.	Hay	8
	Green fodder	10
	Oats	6

	Food.	Amount.	Value in "Starch Equivalent."	Digestible Protein.
1.	Hay	10 lbs.	3·21	0·7
	Oats	5 ,,	3·0	0·45
	Carrots	10 ,,	0·92	0·118
	Total	25 lbs.	7·13	1·27
2.	Hay	10 lbs.	3·21	0·7
	Oat straw ...	5 ,,	0·53	0·064
	Oats	6 ,,	3·6	0·54
	Total	21 lbs.	7·34	1·3
3.	Hay	10 lbs.	3·21	0·7
	Oat straw ...	5 ,,	0·53	0·064
	Maize	2 ,,	1·61	0·16
	Oats	3 ,,	1·8	0·27
	Total	20 lbs.	7·15	1·19
4.	Hay	8 lbs.	2·56	0·56
	Green fodder ...	10 ,,	0·897	0·168
	Oats	6 ,,	3·6	0·54
	Total	24 lbs.	7·06	1·27

The calculations for maintenance diet have been made throughout for a horse of 1,000 lbs. weight, but it

must not be supposed that there is a *direct* proportion between the amount of food required and the weight of the animal. Food requirements are largely determined by the skin surface of the animal, for a large skin surface means a large area for the radiation of heat, and loss of heat must be made up for by the food. Now, it can be shown that a small animal has a larger skin surface in proportion to its weight than a large animal of the same species, and so requires more food in proportion. Thus a pony weighing 500 lbs. requires more than half the amount of food sufficient for a horse of 1,000 lbs., and, on the other hand, a horse of 2,000 lbs. is satisfied with much less than twice the amount given to the 1,000-lbs. horse. Taking the ration for a horse of 1,000 lbs. as the standard, it may be said that, for every 100 lbs. required by such an animal, the approximate amounts required by animals weighing more or less than 1,000 lbs. would be in the following proportions:

	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight of animal ...	500	600	700	800	900
Amount of food ...	63	71	79	86	93

	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lb .	Lbs.
Weight of animal	1,000	1,100	1,200	1,300	1,400	1,500	1,600
Amount of food	100	107	114	120	125	130	135

So that, having determined the amount of food for a horse weighing 1,000 lbs., the quantity for a horse

of 1,500 lbs. is got by multiplying by $\frac{130}{100}$, or 1·3, or for a horse of 600 lbs. by multiplying by $\frac{71}{100}$, or 0·71.

In actual practice no such arbitrary standard can be fixed to suit all cases and all animals. Every horse-keeper knows that some horses will maintain their condition, do their work satisfactorily, and, in short, thrive, on less than the allowance found necessary for the majority of the animals. Others will always require an extra supply over the average allowance. These individual cases have to be provided for, but the figures given above are such as will be found practically useful when applied to a number of animals, where the "good doers" will practically balance the bad feeders.

Whenever an animal is made to do work, the food requirements are increased, and, as we have already seen, all the nutrients in a foodstuff can take part in supplying the energy needed. Energy exists in many forms, and frequently energy in one form may be converted into another. Thus the energy contained in a ton of coal may be set free as *light* obtained from the coal-gas, and this in its turn will give rise to *heat*, which will in its turn produce steam sufficient to do *mechanical work*. Now, there is a definite proportion between the amount of *light*, and *heat*, and *work* got from this ton of coal, so that, knowing the amount of heat generated, the amount of work produced can be calculated. The same holds good for the energy derived from food. There is a definite ratio between the value of a food as a heat-producer and as a work-producer. The relation is such that the amount of heat required to raise the temperature of 1 kilo. (2·2 lbs.) of water 1° C. is equivalent to 3,057 foot lbs., or $\frac{3,057}{2,240}$ foot tons, of work.

This amount of heat—namely, that to raise the temperature of 2·2 lbs. of water 1° C.—is called a (large) Calorie.* If, then, we know the heat value of a food, and the work to be done by a horse, we can calculate the amount of that food necessary to provide for that amount of work. Now, it has been proved experimentally that 1 lb. of starch when completely digested produces 1,710 Calories of heat, and this is therefore equivalent to $3,057 \times 1,710$ foot lbs. of work, or $\frac{3,057 \times 1710}{2,240} = 2,334$ foot tons. But the whole of this energy is not available for external work, for, like every other machine for the transformation of potential energy into work, the body is only able to utilize a part of the power supplied to it. In a good type of steam-engine it is not possible to get more than 15 per cent. of the total energy of the steam out in useful work, whereas the body is much more economical, and gives out as work about 30 per cent. of the energy it receives. Kellner describes a series of experiments with a horse made to turn a braked capstan. The exact amount of work done was ascertained, and of the energy supplied in the digestible food the animal used from 29 to 38 per cent., or on an average about one-third. Thus the actual work-value of 1 lb. of digestible starch is about 778 foot tons. Now, the average maximum amount of work that a horse weighing 1,000 lbs. can do daily is about 6,500 foot tons, so that the amount of digestible starch to be given for *work production* is $\frac{6,500}{778}$, or approximately $8\frac{1}{2}$ lbs. This amount must,

* In English equivalents the amount of heat required to raise the temperature of 1 lb. of water 1° F. is equivalent to 772 foot lbs. of work.

of course, be added to that required for maintenance alone. The method of calculating the work-value of a food by means of its starch equivalent is justified by the results of experiment. Kellner made eighteen tests with horses attached to a braked capstan, and taking 100 to represent the observed amount of work done, he found that the potential work (calculated from the starch equivalents) of the food supplied varied in the various experiments between 96·5 and 103·1, the average being 99·8, a sufficiently near approximation for all practical purposes.

But now the question arises as to the constitution of the working diet. It might at first sight appear as though the extra food needed for work production could all be supplied in the form of carbo-hydrate, or a mixture of carbo-hydrate and fat. This, however, is not the case, and for two reasons. Firstly, when an animal is put to work after a long period of rest, the muscles are soft and out of condition. With moderate work they become gradually firmer and larger, and just as the athlete's muscles develop as he gets fit, so do the muscles of a horse, whether a thoroughbred in training, a hunter, or a draught-horse. There is thus an actual growth of muscle, which can only be supplied by protein in the food, and, further, these largely developed muscles, kept in use and at work every day, will require a greater supply of protein to make good wear-and-tear than the muscles of a resting horse. In the second place, we have already seen that to get the fullest digestion of the nutrients supplied in the food there must be a certain proportion of protein, and this proportion (the nitrogenous ratio) must not be less than about 1 : 10. Thus the whole ration, made up of the maintenance and the

work-producing portions, must contain this minimum amount of protein. For certain kinds of work this wide ratio of 1 : 10 provides insufficient protein for the best results. If a horse is required to work at a high speed, the proportion of nitrogenous matter in the food should be increased so as to bring the ratio to 1 : 8, or at the severest kinds of work to 1 : 5·5 or 6. Beyond this any increase in the proportion of protein is simply extravagant, adding to the cost of the ration without serving any useful purpose.

Taking the maintenance and working requirements together, we arrive at the complete ration for a working horse. In an animal weighing 1,000 lbs. this should contain—

For maintenance	6·5 lbs. digestible starch with	0·65 lb. protein.
For work production	8·5 lbs. digestible starch with not less than	0·85 lb. protein.
Total	15·0 lbs.	1·5 lbs.

In other words, the whole ration must contain the equivalent of 15 lbs. of digestible starch, of which for slow, but hard work, at least 1·5 lbs. should be protein, whilst for very severe or very fast work the protein may well be as much as 2·5 lbs. to 3·0 lbs. For light work, the starch equivalent of the ration must be reduced, or the animal will put on fat, and the cost of feeding will be high in relation to the work done. Applied to a number of horses, the above standard ration can be tested by observing the changes, if any, in the average weights of the animals over a period of three or six months. If the horses were fat and had been overfed at the commencement of the test, they will lose weight, and, for working condition, be the better for it. If overworked, or fed on an insufficient

diet, prior to the test, they will gain weight and improve in condition and appearance. If during the test they are overworked, or the food is poor in quality, and not of average composition and digestibility, they will lose weight and show the effects of wear or starvation. In such a case it is for the wise horse-owner to readjust the conditions of work, and the quality and quantity of the food. Once again, it must be borne in mind that all horses of similar weights, and doing the same work, are not alike in their requirements. The thrifty horse will do well on less than his allowance, whilst another horse in the same stable will require an extra amount to keep him up to his work. These and other similar adjustments will be made by the owner or horse-keeper who takes an interest in the horses under his charge. They are sometimes neglected with disastrous results.

CHAPTER VI.

A SUITABLE RATION.

And, now, having considered the uses of food in the body, the composition, and digestibility of the various foodstuffs, and their real value to the animal in relation to its needs, we are in a position to make up a ration suitable for any particular kind of work. It is, of course, true that many of the most experienced and expert horse-managers know little or nothing of the chemistry or physiology of food, and yet their results are all that could be wished for. These men have learned by long experience, and by adopting, or departing from, the customs of others as seemed good to them. By means of constant observation and a natural genius, they have arrived at a scientific result by rule-of-thumb methods. On the other hand, a large number of horse-owners are not themselves possessed of this faculty, and in most cases they are at the mercy of horse-keepers and grooms, so that a knowledge of the principles of feeding will, it is hoped, enable them to protect themselves from loss, either in the form of a too heavy forage bill, or in that of unsatisfactory condition of their horses.

All rations, however scientifically compounded, have to stand or fall by the one test of practice: Do the horses perform their work in a satisfactory fashion? Do they keep up their condition without losing weight,

and without putting on unnecessary fat? Is the incidence of disease of the digestive tract low? And along with all these, the business man asks one last question: Is this achieved at the lowest possible cost? These are all-important questions which must be answered in the affirmative before the ration can be considered entirely satisfactory.

In this chapter are described the effects of varying conditions, such as age, work, climate, etc., upon the suitability of a ration. Next, the peculiar properties of the different foodstuffs are discussed in order to arrive at their suitability for different purposes. Finally, some suitable rations are suggested for different classes of horses used for different purposes.

In deciding upon a suitable ration for a number of horses many factors must be taken into consideration. Among the chief of these are the age and weight of the horses, the season and climate, and the conditions of work.

The question of **age** is of importance only when young, immature horses are being fed, and has little interest in a discussion of the methods of feeding working horses.

The average **weight** must be taken into account, for with increasing weight more food is required (see p. 48).

The **conditions of work** are, however, usually the factors which really determine the ration, for the amount and kind of food must be proportional to the expenditure of energy. If the exact amount of energy used up at any particular work could be ascertained, then the amount of food necessary to provide for it could be found. This, however, is not practicable, but by common experience of the horse's capacity the amount of work required of

any particular animal may be classed as *light*, *moderate*, or *severe*. The standard requirements of a 1,000-lb. horse for heavy work have already been stated as the equivalent of 15 lbs. of digestible starch, and this amount may be reduced to 13 lbs. for moderate work, and $11\frac{1}{2}$ lbs. for light work.

The matter of **speed** or **pace** is of great importance in arranging a suitable ration, for the reason that the energy expended increases very rapidly with increase of pace. Many experiments have been performed to determine the value of food for work performed at different speeds, and among the most accurate are those by Zuntz. He found that the food required per unit of work increased nearly 70 per cent. in altering the speed from three miles to seven miles per hour. In other words, the performance of a given amount of work costs much more in food when done at a fast pace than at a slow one. In connection with pace, it is further necessary to remember that the "nitrogenous ratio" of the ration must be narrow (1 : 5·5 or 6) for the best results, if the work is to be done at a fast pace. This point is related more or less to the question of the *bulk* of food for different purposes. The horse at fast work, for example a hunter, must have his nutriment in comparatively small bulk, whereas a horse used for slow work on a farm may be allowed a large bulk of less concentrated food from which to extract the nutriment required.

The **duration of work**—*i.e.*, the number of working hours per day—has a bearing upon the question of a suitable ration, for a horse with sixteen hours out at work and only eight in the stable must not waste time on unnecessarily slow feeding. The sooner (within limits) he clears his manger the better, for the rest of

the time indoors he can lie down. Thus, no long hay is given to such a horse, but the necessary amount of hay is fed as chaff, mixed with the corn ration. The corn, too, is crushed to facilitate digestion.

The effect of **climate** and **weather** must not be lost sight of when fixing a ration, for with cold weather the amount of food necessary to keep up the normal body temperature is increased. Thus it is a common practice at the beginning of winter to improve the daily ration by the addition of 1 lb. of beans, although there are no very good reasons why beans should be selected in preference to an equivalent quantity of oats, maize, or barley. However, there can be no doubt that work for horses is harder in winter than in summer, and the practice of giving extra food is quite justified.

The **balance** of the various nutrient substances, digestible proteins, fats, carbo-hydrates, and fibre in the total ration is a matter of supreme importance in deciding upon the suitability of such for any special work.

The "**nitrogenous ratio**" must be determined in every case, and if this falls within the limits suggested (p. 52) as suitable for various classes of work, the food may generally be considered sufficiently well balanced. The first step in finding the "nitrogenous ratio" of a food mixture is to calculate the amount of digestible protein in each of the ingredients, and, by addition, find the total protein of the ration. Thus $n_1 + n_2 + n_3 = N$, where n_1, n_2, and n_3 are the respective amounts of digestible protein in the three foodstuffs of the mixture, and N is the sum of them. The total fats are obtained similarly, and then multiplied by the factor 2·3 (see p. 35) to reduce them to their equivalent value in terms of starch. The carbo-hydrates + digestible fibre of each

ingredient are also calculated and added together. Then the ratio is obtained by comparing the total protein with the sum of the total fats (in terms of starch) and carbo-hydrates, including digestible fibre. Expressed as a formula this is—

$$\frac{\text{N}}{\text{F} \times 2 \cdot 3 + \text{C.-H.} + \text{D.F.}}$$

The nitrogenous ratios of the food supplied to horses under different conditions of age and work must be varied if optimum results are desired.

In the foal, with his great need of protein material for growing muscle and other nitrogenous tissues, the natural food—milk—has a nitrogenous ratio of 1 : 3. This is narrower, or, in other words, represents a higher proportion of protein to other nutrients than is necessary or even suitable under any conditions of work.

For work the narrowest ratio required is 1 : 5·5 or 1 : 6, and this is desirable when the work is severe, and especially if it has to be done at a high speed. The thoroughbred, the hunter, and the fast harness-horse, need this high proportion of protein, and, similarly, though perhaps to a less extent, the heavy van-horse worked at a trot, as in London, and even the heavy dray-horse, where the hours are long, the work hard, and severe calls are made frequently upon the animal's strength in starting heavy loads. For slower work, such as that of the farm, or where the working hours are short, and only moderate exertion is called for, a ratio of 1 : 8 is quite sufficient. For resting horses in good condition the maintenance ratio of 1 : 10 answers all requirements (see p. 46). The calculation of the "nitrogenous ratio" of a complete ration is shown in the examples on p. 76.

The "**fatty ratio**," in which the total digestible fat is compared with the total digestible protein, is of little practical importance. A very large proportion of fat in a ration is unsuitable for horses, because it lowers the digestibility of the other nutrients, and it is found that the maximum quantity of digestible fat which can be fed without this ill-effect is about 1 lb. per 1,000 lbs. weight of the horse. Now, the total amount of digestible protein in a ration for a horse of 1,000 lbs. weight at severe work need never exceed 3 lbs., and, in fact, is usually nearer 2 lbs. Thus the fatty ratio should be within the limits 1 : 2 and 1 : 3, and *should not be narrower than* 1 : 2. There is, however, no objection whatever to the ratio being *wider* than this—*i.e.*, to the amount of fat being much lower than the maximum of 1 lb.—for, as stated elsewhere (p. 37), digestible carbo-hydrates can replace fat in the ration without any loss of efficiency. As a matter of fact, the foodstuffs fed to horses contain comparatively small amounts of fat, and the total amount in a ration rarely, if ever, exceeds the maximum suggested above. Thus, provided the "nitrogenous ratio" is suitable, and the total amount of nutrients sufficient, the "fatty ratio" may usually be neglected in estimating the value or suitability of a ration.

And now it is necessary to warn the reader against the very real danger of thinking that two foodstuffs of equal nutritive value may always be substituted, the one for the other, in a ration for horses, and be equally suitable. This is emphatically not the case. On inspecting Table III. (p. 42) it will be noticed that at average prices **maize** provides the most nutriment at the lowest cost, and, further, it is the most digestible of foods. The question may be asked, and that with reason, "Why

give any oats, or bran, or other more costly foods? Why not feed maize alone as the corn of the ration? Or, to carry the question to its logical conclusion, Why not omit the costly hay of the ration and feed maize alone?" The answer is that maize alone would be quite *unsuitable.* It has already been stated that maize is wanting in fibre, and causes serious intestinal obstruction, unless some hard hay or straw-fibre is fed with it. Even as the only grain part of the ration, it is less suitable than a mixture of grains, for, given alone, it tends to produce a somewhat flabby condition of the muscles, occasionally a tendency to skin rashes (humour) or "grease," and there is noticed a want of alertness and freshness in horses so fed as compared with those fed on oats. On the other hand, the theories advocated so strenuously by some people that only oats can give that virility and vitality so desirable in working horses, have been shown by experience to be much exaggerated. The practical result of experience is that maize can be usefully fed along with other grains to horses for almost any kind of work, with great economical advantages, but that 10 to 12 lbs. a day must be considered the maximum for the best results.

For thoroughbreds in training, and for hunters and polo ponies, it is still true that **oats** alone, or oats with a few old beans, provide the best corn ration.

Beans and **peas** are of great value on account of their high percentage of digestible protein, and may be used in small amounts—up to 3 lbs. per day—to improve the nitrogenous ratio of an otherwise poor ration. Excessive amounts of peas or beans are inadvisable (see p. 64), and are generally believed to cause gummy legs, a predisposition to lymphangitis, and skin rashes (humour).

A foodstuff of recent introduction in this country is **gram**. It has long been a staple food for horses in India, and in composition it much resembles the ordinary white pea. Exact experiments are wanting with regard to its digestibility, but assuming this to be somewhat similar to that of peas, gram might well be used as a highly nitrogenous concentrated food to mix with foods wanting in proteins. At the present time it is being used, with good results, in amounts up to 4 or 5 lbs. daily, as a substitute for beans.

Bran as a food is dear, when tested by its cost in relation to nutritive value alone (see Table IV, p. 73), but it has very valuable properties of use in feeding sick or resting horses, and for this reason and under these circumstances it is an economical and necessary purchase. The flakes of bran exert a slightly irritant mechanical effect on the intestinal mucous membrane, and this accounts for the laxative properties of bran-mashes. It contains a fairly high percentage of salts, especially phosphates, and the excessive use of bran has often been thought to be associated with the formation of intestinal calculus (stone). As part of the daily ration, bran has no great advantages, and its cost per nutritive unit is so high that it must be considered too expensive for general use.

Barley as a food for working horses is not very commonly used. There has, in fact, been a good deal of prejudice against the use of barley, but numerous experiments,* and, more recently, practical experience of its use in a mixture of grains, have proved that it can be safely fed with good results whenever its market price

* See "Note on the Use of Barley as Horse Food," by John Malcolm, F.R.C.V.S., Birmingham, *Journal of Comparative Pathology*, vol. ix., p. 203.

makes it less costly than some other grain in the ration. As a general rule, it may be substituted for an equivalent amount of oats to the extent of 6 or 7 lbs. a day, but to horses unused to it this amount should be introduced gradually. The parching of barley has sometimes been advocated to improve the digestibility, but slight crushing is probably the best preparation it can be subjected to.

Wheat is usually too costly to be fed to horses, if we except the damaged or unmarketable wheat sometimes given to farm horses. It has generally been held to be a dangerous food, giving rise to indigestion and colic, and fed in large quantities, and particularly if new, this is undoubtedly true to some extent. On the other hand, old, hard wheat can be, and has been, fed to horses in small amounts without any ill-effects, and, in certain conditions of the corn market, with economy. It cannot, however, be advised generally, nor does its price often make its introduction economically desirable.

Dried brewers' grains can be fed to horses with advantage in amounts not exceeding 3 or 4 lbs. daily, and from their high protein content materially improve a low nitrogenous ratio. They are appetizing, and are relished by horses as part of a mixture.

As stated above, it is necessary that horses should be supplied with **hay**, but the kind of hay to be given depends on the class of horse and the nature of the work. For hunters and light harness-horses meadow hay is the best. It is not too bulky, has the least amount of crude fibre, and so both for the "wind" and for digestion of the other ingredients of the ration is preferable to clover, sainfoin, and other mixtures. For a horse engaged in fast work—*e.g.*, a hunter—it is a

mistake to give much bulky food before work, and for this reason long hay is best given at night, and only a little chaff with the corn in the morning. For light horses receiving much maize, some hard hay, such as *timothy* or *cocksfoot* hay, is the best, for reasons already given. For the heavier draught-horses, bulk is important and necessary; if maize is fed, fibre must be provided in the hay, so that the coarser hays such as clover, or clover and rye grass, or sainfoin, are the best. Usually, no long hay is given, or, at any rate, the bulk of the hay is cut into chaff; and if meadow hay is used, it may be advisable to mix with it some oat-straw to give the desired bulk.

Straw as food for horses has only a very limited use—in fact, only oat-straw is admissible, and that only to combine with meadow hay as already described. As Zuntz's experiments have so clearly proved, the work necessary to digest and propel along the intestine such a material as wheat-straw exceeds the energy value of the straw given, so that the animal loses, rather than gains, energy when wheat-straw is given.

And now, turning to the consideration of actual rations, it is well to examine some faulty examples to see wherein the errors lie.

These can be divided into two groups—namely, (1) errors of *balance* of the ration, and (2) errors relating to the *cost* of the ration. The balance is often faulty in that too high a percentage of protein is supplied; less commonly the proportion of protein is too low. The cost is often excessive because substitutional dieting is not understood, and because of the exaggerated value set upon certain articles of food.

As an example of the former, the following ration may

be taken: A number of harness-cobs about 14 hands high, and averaging twenty to twenty-five miles a day, receive a ration consisting of hay 14 lbs., split beans 7 lbs., divided into four feeds a day. Here the work must be considered moderate, and, assuming the average weight of the cobs to be 700 lbs., the standard requirements are $\frac{79}{100}$ths of those for a 1,000-lbs. horse—*i.e*, about $\frac{4}{5}$ths of 13 lbs. starch equivalent, or $10\frac{1}{2}$ lbs. The work being fast, the "nitrogenous ratio" should approximate to 1 : 6.

By calculation from Tables III. and VIII., we see that—

Ration.	Starch Equivalent.	Digestible Protein.	Digestible Nutrients other than Protein.
	lbs.	lbs.	
Hay, 14 lbs.	4·5	0·98	5·131
Beans, 7 ,,	4·92	1·55	3·53
Total 21 lbs.	9·42	2·53	8·66

with a nitrogenous ratio of $\frac{2 \cdot 53}{8 \cdot 66}$, or $\frac{1}{3 \cdot 4}$.

In this ration calculation reveals at once that the total food supplied is somewhat below the requirements, and that the proportion of nitrogenous matter is unnecessarily high.

It may be urged in extenuation that the amount of food mixture given daily is not rigidly fixed, but is varied according to the severity of the work, but obviously this can only be done where the number of horses is small, and the owner able to supervise their

feeding. Even if this were done, it would not rectify the excessive proportion of protein. The better method would be to substitute a food rich in carbo-hydrates, such as maize or barley, for part of the beans according to the method described in Chapter VIII., when the food would be better balanced. Such a substitution, using maize for part of the beans, would at average prices show a diminution of cost, or alternatively, if the cost were left unchanged, more food might be given daily.

As an illustration of a too costly ration we may take the following: A large stud of heavy dray-horses are fed on a mixture consisting of hay 20 lbs., oats 20 lbs., giving on calculation—

Ration.	Starch Equivalent.	Digestible Protein.	Digestible Nutrients other than Protein.
Hay, 20 lbs.	6·42 lbs.	1·4 lbs.	7·33 lbs.
Oats, 20 ,,	12·0 ,,	1·798 ,,	10·896 ,,
Total, 40 ,,	18·42 ,,	3·198 ,,	18·226 ,,

With a nitrogenous ratio of $\frac{3\cdot198}{18\cdot226}=\frac{1}{5\cdot7}$.

The substitution of the maize-beans mixture for part of the oats, as shown on p. 79, would materially lessen the cost of feeding without any loss of efficiency. Other suitable substitutions would be a mixture of gram and maize, or gram and barley, or even brewers' grains, for part of the oats.

Before concluding this chapter, it may be advisable to give a few typical rations suitable for different classes of horses doing various kinds of work:

Ration.	Starch Equivalent.	Total Digestible Protein.	Nitrogenous Ratio.
1. *Thoroughbred in Training.*	lbs.	lbs.	
Hay ... ... 8-10 lbs.* Oats ... ... 14-18 ,,	14·01†	2·32†	1 : 5·8†
2. *Hunter in the Season.*			
Hay (chaff) ... ... 6 lbs. ,, (long) ... ... 4 ,, Oats ... ... 14 ,, Beans ... ... 1 lb.	12·33	2·17	1 : 5·4
3. *Carriage-Horse at Regular Work.*			
Hay ... ... 12 lbs. Oats ... ... 12 ,, Beans ... ... 1 lb. Bran ... ... 1 lb.	12·27	2·25	1 : 5·4
4. *Bus-Horse.*			
Hay ... ... 12 lbs. Maize ... ... 10 ,, Oats ... ... 2 ,, Barley ... ... 2 ,, Peas ... ... 3 ,,	16·45	2·55	1 : 6
5. *Parcel Vanner.*			
Hay ... ... 14 lbs. Oats ... ... 6 ,, Maize ... ... 8 ,, Beans ... ... 2 ,,	15·93	2·6	1 : 5·8
6. *Heavy Vanner.*			
Hay ... ... 14 lbs. Maize ... ... 10 ,, Oats ... ... 8 ,, Beans ... ... 2 ,,	18·75	2·94	1 : 6
7. *Heavy Dray-Horse.*			
Hay ... . 18 lbs. Maize ... ... 10 ,, Oats ... ... 6 ,, Beans ... ... 3 ,,	19·53	3·26	1 : 5·7

* The amount and kind of hay fed daily varies greatly with different trainers.

† Calculation on the larger limit.

CHAPTER VII.

THE COMPARATIVE COST OF VARIOUS FOODS.

In judging the cost of any foodstuff, we must first of all estimate its real nutritive value as described in a previous chapter (Chapter IV.), so as to have a standard of comparison by which to test its money value. The market price of a food depends on many varying circumstances, and may have no relation whatever to the feeding value. If the foodstuff is highly esteemed and greatly in demand, the price may be much higher than the intrinsic value of the food warrants. If the supply is short, due to a bad crop, or a sudden increase in the demand, again the market price will rule high, and, judged by its nutritive value, the food will be dear. Sometimes the whole or part of a foodstuff may be used for other commercial purposes, and so the demand may fluctuate with consequent variation in the price.

We have seen that various foods differ greatly in composition, in digestibility, and in heat and work producing power, and in estimating their monetary value these three factors must be taken into consideration. For the purpose of applying this knowledge practically, a table can be constructed showing the composition, percentage

digested, heat units provided, and market price of a food, and thus the price per 100 heat units is made evident. We thus obtain some idea of the relation between the market price of the food and the benefit to the horse. We also see at once that in one food the heat units are bought at a high figure, or, in other words, are dear; whilst in another food the heat units are much lower in price, and yet have exactly the same nutritive value in the body of the horse.

This may be illustrated by the examples of beans and maize:

	Market Price.	Heat Units in 100 lbs.	Price per 100 Heat Units.
Beans	35s. for 504 lbs.	70·32	9s. 10½d.
Maize	27s. 6d. for 480 lbs.	80·57	7s. 1½d.

It must be borne in mind, however, that beans contain a much greater percentage of the costly proteins, the essential elements in a diet, than does maize. Thus beans have a high value for mixing with other substances of a low protein content in order to bring the mixture up to the required nitrogenous ratio. For this reason, whilst the price per unit is higher than in maize, beans are worth their price because of this power of improving and bringing up to standard requirements the cheaper but less nitrogenous foodstuffs.

At the same time, if the mixed ration contains the required amount of nitrogenous matter, but is wanting in total nutritive value, the defect can be made up by

selecting that food which contains the necessary heat units at the lowest price, and so an addition of maize would answer every requirement, and that at a cheaper rate than if the same weight of beans were added.

We can, of course, apply the same method in testing the comparative cost of complete rations. The two rations given below are fed to two large studs of horses in London, and they are selected for the reason that at the prices given in the tables the weekly cost is practically the same in each case. The question to be determined is as to which stud is getting the better value for the money spent.

Ration I.

Daily Food per Horse.	Market Price.*	Cost in Pence.	Value in Heat Units or Starch Equivalent.
Hay, 16 lbs. ...	70s. per ton	6d.	5·13 lbs.
Oats, 14 ,, ...	17s. per 320 lbs.	8·925d.	8·42 ,,
Maize, 2 ,, ...	22s. per 480 ,,	1·1d.	1·61 ,,
Bran, ¼ lb. ...	82s. 6d. per ton	0·26d.	0·3 ,,
Total 32¼ lbs. ...	—	16·285d.	15·46 ,,

Therefore 32¼ lbs. costs 16·285d., and provides the equivalent of 15·46 lbs. of digestible starch; or, weekly, 328 lbs. costs 9s. 6d., and provides the equivalent of 108·2 lbs. of digestible starch.

* The market prices taken in this and the following example were current a year or two ago. They are very different from to-day's prices, but this in no way affects the value of the examples as illustrations of the argument in the text.

RATION II.

Daily Food per Horse.	Market Price.	Cost in Pence.	Value in Heat Units or Starch Equivalent.
Hay, 16 lbs. ...	70s. per ton	6d.	5·13 lbs.
Oats, 4 lbs. ...	17s. per 320 lbs.	2·55d.	2·4 ,,
Maize, 6 lbs. ...	22s. per 480 ,,	3·3d.	4·83 ,,
Beans, 2 lbs. ...	31s. 6d. per 504 lbs.	1·5d.	1·4 ,,
Bran, 2 lbs. ...	82s. 6d. per ton	0·883d.	1·075 ,,
Dried grains, 2 lbs.	110s. per ton	1·18d.	1·076 ,,
Plus an additional 2 lbs. of above mixture ...	—	0·921d.	0·99 ,,
Total 34 lbs. ...	—	16·334d.	16·9 ,,

Therefore 34 lbs. costs 16·334d., and provides the equivalent of 16·9 lbs. of digestible starch; or, weekly, 328 lbs. costs 9s. 6½d., and provides the equivalent of 118·3 lbs. of digestible starch.

Thus, in this example is illustrated the fact that **market price is no guide to nutritive value,** for at the same weekly cost the two studs receive rations showing a difference of 10 heat units. Now 1 heat unit is the amount of energy or work supplied by 1 lb. of digestible starch, so that Ration II. is better than Ration I. by 10 lbs. of digestible starch a week, a very considerable item.

It is necessary, however, to determine the nitrogenous ratios of the two rations before condemning Ration I. offhand, but when this is done it will be found that both dietaries are rich in nitrogenous foods, and both show

ratios much above the required standard for hard work:

$$\frac{\text{Total nitrogenous substances}}{\text{Total carbohydrates} + \text{total fats} \times 2{\cdot}3} = \overset{\text{Ration I.}}{\frac{1}{5{\cdot}8}} \text{ and } \overset{\text{Ration II.}}{\frac{1}{5{\cdot}1}}.$$
(including digestible fibre)

And here, again, Ration II. proves to be the better food, whilst both rations are unnecessarily rich in proteins.

It may be urged by some that oats and hay alone form the best food for horses, and that the smaller the admixture of maize the better. Whilst not denying the merits of oats and hay, there are practical tests which can be applied in the case of every ration, and it is well to apply them before condemning a ration which is effecting a considerable financial saving. These test questions are: (1) Do the horses perform the work required of them satisfactorily? (2) Do they keep up their condition without losing weight? (3) Is the incidence of colic (digestive tract diseases) any higher than when on the old ration? and (4) Is the average working life of the horses as long as formerly?

With any large stud of working horses these questions can very soon be answered, and on the replies will depend the endorsement or condemnation of the ration fed.

But to return to the Rations I. and II. considered above, it is obvious that if Ration I. is enough for the needs of a large number of horses of a similar type, and doing similar work, to those fed on Ration II., then the latter ration (II.) is unnecessarily liberal, and might

be reduced with a consequent lessening of the cost. If the additional 2 lbs. of the mixture were taken off, reducing it to 32 lbs. of food per diem, it would still be better than Ration I. by 3 lbs. of digestible starch per week, and the cost would be reduced 6½d. per horse per week, and would be 6d. per week cheaper than Ration I. Subject to the tests described above, this would be a **legitimate saving** of 26s. per year per horse, a considerable item for a firm employing a large number of horses. *Per contra* it is quite possible that Ration I. is insufficient when tested as described.

It should be pointed out that one item has been omitted from the cost of these rations—namely, the expense of mixing and preparing. Here, other things being equal, a ration containing six ingredients is more expensive than one containing only four, so that unless there is some advantage in increase of nutritive value, or lessening of prime cost, the greater expense in preparation would make this a dearer food. As we have seen, there is advantage in both these directions, and so the extra charge for mixing is justified.

Thus, by means of a careful analysis of the various items in a diet, their nutritive values, market prices, and relation to each other, it is possible to ascertain the real value obtained for money expended, and, further, by suitable alterations and substitutions, considerable saving in the weekly forage account can be effected without loss of efficiency in the horses.

The table given below, Table IV., shows the cost of 100 heat units obtained from each of the common foodstuffs at an average price:

TABLE IV.

The Comparative Cost of the Heat Units of Various Foods at Average Prices.

Food.	Market Price.	Heat Units in, or Starch Equivalent of, 100 lbs.	Cost of 100 Heat Units.*
Oats	18/- per 320 lbs.	60	9/4½
Maize	25/- ,, 480 ,,	80	6/6
Beans	33/- ,, 504 ,,	70	9/4½
Peas	31/- ,, 504 ,,	67	9/2½
Gram	28/- ,, 504 ,,	62	8/11½
Wheat	30/- ,, 448 ,,	74	9/0¾
Barley	22/- ,, 448 ,,	67	7/4
Rye	25/- ,, 448 ,,	66	8/5¾
Broad bran ...	110/- ,, 1 ton	53	9/3¾
Dried grains ...	100/- ,, 1 ,,	54	8/4
Meadow hay (best)	80/- ,, 18 cwt.	32	12/4¾
Clover hay ...	85/- ,, 18 ,,	29	14/6½
Sainfoin hay ...	85/- ,, 18 ,,	30	14/0½
Oat straw ...	30/- ,, 1,296 lbs.	10	23/3¼
Wheat straw ...	30/- ,, 1,296 ,,	1	230/9¼

* The heat unit used throughout is the heat value of 1 lb. of digestible starch when oxidised in the animal body. The number of heat units in 100 lbs. of a food is therefore called the "starch equivalent" of that food.

CHAPTER VIII.

SUBSTITUTIONAL DIETING AND THE PRACTICE OF SUBSTITUTION.

Having fixed a ration suitable to the needs of any stud of horses, it is not, as a rule, wise to make changes in that ration for any but weighty reasons. Foodstuffs vary in price, however, from time to time, and even a slight fluctuation in the market price may mean a considerable sum in the aggregate when a large number of horses are being fed. Shortage of a foodstuff, or a bad harvest in any particular country or district from which a large part of the usual supply is obtained, may produce such an increase in price that a change to some other article of food is clearly indicated. Now for any substitution to be wise, assuming the original ration to be a sound one, it must conform to the following conditions:

1. The food substituted must be of the same nutritive value in starch equivalent as that taken out of the ration.

2. The proper balance—especially the nitrogenous ratio—of the ration must not be interfered with.

3. The food substituted must be cheaper, in price of its nutritive units, than the one in former use.

It is because of the difficulty in meeting these required conditions that substitution is not more commonly

practised, or where it is done, that it is so often unsatisfactory.

In the case of the horse there are some foodstuffs which are inevitable, and for which no substitute can be found. Such a one is hay in one or other form, and, therefore, it is useless to look about for alternatives. Whatever its price, a horse needs hay, and nothing else can take its place. With corn, however, the case is different. Oats are rightly considered the ideal concentrated food for horses. To supply all the corn a working horse requires in the form of oats is, however, an expensive method of feeding, and it is usually possible to substitute for part, or even the whole, of the oats fed daily some other foodstuff or mixture of foodstuffs at less cost, and yet without loss of nutritive material to the horse. Alternatively, if the diet is insufficient for the needs of the animal, it is frequently possible by substitution to increase the nutritive value without increasing the cost. The choice of foodstuffs suitable for taking the place of oats in the ration is practically limited to maize, barley, rye, wheat, and dried grains, together with beans, peas, or gram, in small amounts. All these substances have high starch-equivalent values, and little waste matter in the form of water, or crude fibre. They vary considerably, however, in protein content, and this variation renders their substitution for oats more complicated than it otherwise would be. The first step then, in deciding on a substitute for part of the oats of a ration, is to find the nitrogenous ratio of the complete ration in its original form. If the percentage of protein in the complete ration is high, then it may be that the substitution of 2 or 3 lbs. of oats by means of its equivalent in *pure starch*, without any protein at all,

would still leave the nitrogenous ratio of the ration at a suitable level. In that case the food costing least per heat unit (see Table IV., p. 73) would be chosen, and the necessary amount, containing the equivalent in starch of the 2 or 3 lbs. of oats, would be substituted. Usually, unless prices were altogether exceptional, the food selected would be maize.

To take an example, a number of horses weighing on an average 1,500 lbs., and doing severe work, are fed on the following ration: Hay, 15 lbs.; oats, 15 lbs.; beans, 3 lbs.; bran, 1 lb.; and it is desired to find a substitute for part of the oats. The oats are costing 17s. 6d. per 320 lbs., and the foodstuff substituted must cost no more, and yet be higher in nutritive value than the oats deleted, for the horses are losing condition. In such a case the first step is to find the real value of the original ration—*i.e.*, the one being fed at the time, by the method described in Chapter IV.

By calculation from Table III. we see that—

Ration X (1).	Digestible Protein.	Digestible Nutrients other than Protein.*	Starch Equivalent.
Hay, 15 lbs. Oats, 15 ,, Beans, 3 ,, Bran, 1 lb.	1·05 lbs. 1·35 ,, 0·665 lb. 0·11 ,,	5·497 lbs. 8·172 ,, 1·515 ,, 0.453 lb.	4·815 lbs. 9·0 ,, 2·11 ,, 0·537 lb.
Total, 34 lbs.	3·175 lbs.	15·637 lbs.	16·462 lbs.

And the nitrogenous ratio is $\frac{3{\cdot}175}{15{\cdot}637}$, or $\frac{1}{4{\cdot}9}$.

Now, by reference to Chapter V. (p. 48) we see that the standard requirements for a horse weighing 1,500 lbs.,

* Digestible nutrients other than protein=
Fats × 2·3 + Carbo-hydrates + Digestible fibre.

and doing severe work, are: $15 \times \frac{130}{100}$, or 19·5 lbs. digestible starch, with a nitrogenous ratio of $\frac{1}{5 \cdot 5}$ to $\frac{1}{6}$. Thus the original ration is deficient in total nutritive units, and at the same time unnecessarily nitrogenous.

Now let us substitute 5 lbs. of maize for 5 lbs. of the oats, and the figures become—

Ration X (2).	Digestible Protein.	Digestible Nutrients other than Protein.	Starch Equivalent.
Hay, 15 lbs.	1·05 lbs.	5·497 lbs.	4·815 lbs.
Oats, 10 ,,	0·899 lb.	5·448 ,,	6·0 ,,
Maize, 5 ,,	0·4 ,,	3·66 ,,	4·0 ,,
Beans, 3 ,,	0·665 ,,	1·515 ,,	2·11 ,,
Bran, 1 lb.	0·11 ,,	0·453 lb.	0·537 lb.
Total, 34 lbs.	3·124 lbs.	16·573 lbs.	17·462 lbs.
With a nitrogenous ratio of $\frac{1}{5.8}$.			

Here, again, the total nutritive value is below the standard, and the protein excessive, so that a further substitution of 5 lbs. maize for 5 lbs. of the oats can be made, with the figures—

Ration X (3).	Digestible Protein.	Digestible Nutrients other than Protein.	Starch Equivalent.
Hay, 15 lbs.	1·05 lbs.	5·497 lbs.	4·815 lbs.
Oats, 5 ,,	0·45 lb.	2·724 ,,	3·0 ,,
Maize, 10 ,,	0·8 ,,	7·32 ,,	8·0 ,,
Beans, 3 ,,	0·665 ,,	1·515 ,,	2·11 ,,
Bran, 1 lb.	0·11 ,,	0·453 lb.	0·537 lb.
Total, 34 lbs.	3·075 lbs.	17·509 lbs.	18·462 lbs.
With a nitrogenous ratio of $\frac{1}{5 \cdot 7}$.			

And now the ration approximates sufficiently to the standard; the substitution of 10 lbs. of maize for 10 lbs. of oats has added to its nutritive value, and, at the same time, the cost has not been increased, but rather slightly lessened. The saving in cost depends, of course, on the market price of oats and maize, but with oats at 17s. 6d. per 320 lbs., and maize at 25s. per 480 lbs., the saving would be—

10 lbs. oats, costing	6·562d.
10 lbs. maize „	6·25d.
	·312d.

or more than $\frac{1}{4}$d. per day per horse.

In feeding 100 horses this amounts to a saving of £47 9s. in the year, but, in addition, there will be an improvement in condition and greater capacity for work.

Suppose, in practice, such a substitution were decided upon, it is necessary to remember that *the change should be made gradually*, otherwise digestive disorder and colic will result. Further, the hay of such a ration must be hard and possess a fair amount of fibre, so that it may be advisable to substitute some sainfoin hay or mixture for part of the meadow hay.

The same methods can be applied in the case of a ration in which the proportion of nitrogen is up to the standard requirements but not excessive. In this case, however, the foodstuff substituted for any part of the ration must contain approximately as much digestible protein as the food deleted.

An example of this sort is furnished by the following: The present ration consists of—hay, 16 lbs.; oats, 20 lbs. oat-straw, 4 lbs. By calculation from Table III. we see that—

Original Ration.		Digestible Protein.	Digestible Nutrients other than Protein.	Starch Equivalent.
Hay	16 lbs.	1·12 lbs.	5·864 lbs.	5·136 lbs.
Oats	20 „	1·798 „	10·896 „	12·0 „
Straw	4 „	0·051 lb.	1·11 „	0·4284 lb.
Total ...	40 „	2·969 lbs.	17·87 „	17·564 lbs.

With a nitrogenous ratio of $\frac{2 \cdot 969}{17 \cdot 87}$, or $\frac{1}{6}$.

It is desired to substitute some other foodstuffs for half the oats, to give exactly the same total nutritive value, whilst not falling much in total protein.

Here it is evident that maize alone will not suffice, for maize has a lower content of protein than oats. A mixture of beans and maize, made up of 30 per cent. beans and 70 per cent. maize, approximates fairly closely to the nitrogenous value of oats, so that it is necessary to find how much of this mixture would be required to take the place of 10 lbs. of oats.

Now, 100 lbs. maize has a starch-equivalent value of 80 (Table III.).

∴ 70 „ „ „ „ $\frac{80 \times 70}{100} = 56$.

Similarly, 100 lbs. beans „ „ 70 (Table III.

∴ 30 „ „ „ „ $\frac{70 \times 30}{100} = 21$.

Therefore 100 lbs. of the maize-beans mixture (70 lbs. maize, 30 lbs. beans) has *a starch-equivalent value of 77*.

Again, 100 lbs. oats has a starch equivalent value of 60 (Table III.)

∴ 10 „ „ „ „ 6.

But 77 represents the value of 100 lbs. maize-beans mixture.

∴ 6 „ „ $\frac{100 \times 6}{77}$

$= 7 \cdot 79$ *lbs. maize-beans mixture.*

In other words, 10 lbs. of oats can be substituted by $7\frac{4}{5}$ lbs. of maize-beans mixture; thus—

Revised Ration.	Digestible Protein.	Digestible Nutrients other than Protein.	Starch Equivalent.
Hay, 16 lbs.	1·12 lbs.	5·864 lbs.	5·136 lbs.
Oat, 10 ,,	0·899 lb.	5·448 ,,	6·0 ,,
Maize } Beans } 7·8 lbs.	0·734 ,,	5·178 ,,	6·0 ,,
Oat-straw, 4 lbs.	0·051 ,,	1·11 ,,	0·428 lb.
Total, 37·8 ,,	2·804 lbs.	17·6 ,,	17·564 lbs.

And the nitrogenous ratio is still $\frac{1}{6}$.

If the prices of oats, maize, and beans are 17s. 6d. for 320 lbs., 25s. for 480 lbs., and 33s. for 504 lbs. respectively, the saving effected by the substitution is as shown below—

20 lbs. oats cost	13·124d.
10 lbs. oats cost	6·562d.
7·78 lbs. maize-beans mixture ...	5·249d.
	11·811d.

∴ saving = 13·124 − 11·811d. = 1·3d. per horse per day; or in feeding 100 horses, a saving of £197 14s. a year.

These examples serve, then, to show the methods to be adopted in substituting one food in a ration by another, and by means of the tables included in this volume the calculations necessary are reduced to a minimum.

It must be remembered that the idea of the equivalent value of two foods in terms of any common unit (such as 1 lb. digestible starch, the unit used throughout these pages) can be carried too far, and before attempting any substitution, Chapter VI. on "A Suitable Ration" should be carefully read.

CHAPTER IX.

THE PREPARATION OF FOOD.

Having purchased good quality foodstuffs, it is necessary to consider whether they shall be subjected to any special preparation before being placed in the manger. The various processes by which food is cut, crushed, sifted, cleaned, and mixed, add considerably to its cost, first, by reason of the capital expenditure on plant, and, secondly, in payment of the labour involved. Thus, unless the saving effected is demonstrably in excess of the expenditure, this food preparation is an uneconomical process.

Some horse-owners, mostly those whose animals are not kept for commercial purposes, feed them on whole oats, bran, and long hay, and on such a diet they undoubtedly do well. This simple method is, however, not applied to working horses for reasons which will appear later. It is often urged that the horse's teeth are veritable grinding machines, and that the food should be given, without any preparation, in its natural state. But the working horse is not by any means under purely natural conditions, and although well adapted to domestication, Nature cannot be invoked in support of this contention. Practical experience proves that it is necessary and advisable to resort to methods of preparation to counteract the evils of domestication. A large amount of

energy is required from the horse to crush his corn and cut up his hay, and this energy is a first charge upon the food consumed. This can be saved to a considerable extent by mechanical means. Moreover, time is taken to completely masticate a bulky meal, part of which can be done by machinery, and thus the animal can get through his food in the time that is usually allowed for a man's dinner. This point is made more evident when it is remembered that although a horse may have the same meal-hours as his driver, the bulk of food he requires in proportion to his weight is many times greater. Abnormal digestive conditions often appear to arise from uncrushed corn taken hurriedly, and, further, proper sifting removes dust and foreign metallic bodies, thus lessening the incidence of disease and death. When the saving (1) of animal energy, (2) of time at the manger, (3) of loss of working time due to diseases of the alimentary canal, and even (4) of deaths, by the proper preparation of foodstuffs is taken into consideration, this process is not only justifiable and economical, but is a necessity.

The degree of preparation and the machinery whereby this is affected may vary considerably according to the dictates of the horse-owner, the kind of foodstuffs used, and the number of horses to be fed. Thus there are variations in plant, from the simple chaff-cutter and corn-crushers on one floor, with layer and shovel mixing on the one below, up to the large provender mills of the railway, horse-bus, and transport companies. In some cases there is an additional small plant for soaking or cooking. In the present chapter it is proposed only to treat of chaff-cutting, corn-crushing, and mixing in the dry state. The various processes of steaming and cooking will not be described, as their use is not

general, and, further, because, although the advocates of cooked food claim great advantages for it, experimental evidence shows quite clearly that digestibility is considerably lessened by the process.

The essentials of a provender mill are much the same in the case of a small or large stud; a short description of a mill will suffice to show the important features. The building should be a three-storied one. The hay and corn is drawn up into the third storey for storage, and later to be handled and placed in bins, supplying the chaff-cutters and corn-crushers which are on the second floor. The chaff and crushed corn from each of these is mixed in a worm which leads to a bin with a sack spout opening on the first floor. Here the bags of mixture can be shoved or slid down a shoot into drays for despatch. The ground floor will be occupied by the engine and machinery store. All these rooms should be well lighted and ventilated. The floors must be of concrete or a similar material. These conditions help to make the mill proof against rats, and allow of the proper cleansing so necessary to keep down fungoid, insect, and other pests, which naturally considerably lessen the nutritous value of a food.

At the commencement of milling operations, a "set" of material will first be prepared. Thus, suppose the daily allowance for each horse is:

	Lbs.
Chaff	14
Oats	7
Maize	7
Beans	2
Bran	2
Total	32

and we wish to prepare a week's supply for sixty horses, we should multiply each weight by 420 (7 days × 60 horses) and reduce the hay to cwts, and the grains to "sacks" or their common measure. All would be weighed and the grains put into their proper bins on the third floor; the hay would be forked so as to feed the chaff-cutter, and the bran would run directly into the mixing apparatus, as it requires no treatment.

On the second floor, the hay is cut into chaff or chop and dust is extracted by means of an air draught, the tube of which leads to a special dust-collecting chamber. Before passing into the various crushers, the grains are sifted so that foreign material is removed, and later the corn passes over magnets to remove metallic bodies. Each ingredient now reaches a mixing worm or roller; the rate at which they do this can be controlled so that various weights in a food are in the right proportions. At the end of the mixing apparatus is a bin to receive the mixture, and from this container on the first floor is a spout, at the end of which sacks can be filled to a given weight. The end of the sacking spout is usually shaped like an inverted Y, so that the mixture can be turned from one bag into another as they fill.

During its journey to the bag the food has been subjected to different processes, and these must now be considered. It has already been mentioned why chaff-cutting is advisable. The length of the cut pieces should be from ¾ to 1 inch. If chaff is longer, the grain separates out more easily, and no real advantage is gained by having it shorter.

The value of dust extraction must be great if dusty food has the same effect upon the horse's lungs as it has upon the respiratory organs of men working in the mill. In addition to this injurious effect upon the "wind,"

dust also hinders digestion in a similar manner to that already pointed out (p. 26, rabbit and flour). The pasty mass which results is often thought to assist in the formation of intestinal stones.

The hard cereal grains and leguminous seeds are nearly always subjected to some form of pressure, which varies in degree from simple bruising, down to the formation of a floury material. Accordingly, we have the terms *bruised*, *crushed*, and *rolled* oats, *kibbled* beans, and *split* beans. A moderate degree of crushing is, however, the most desirable in almost all cases. Many horse-owners question the value of crushing oats, and some even condemn it as being wasteful. However, properly crushed oats have been shown by experiment to be 4 per cent. more digestible than whole grain. There are other advantages which were noted earlier in this chapter. Horses appreciate crushed oats, and eat them up quickly. That the mechanical mastication has been of value is shown by the occurrence of colic when whole oats are suddenly substituted. Similar remarks may be made with regard to maize and beans. The former is increased in digestibility by 7 per cent. Moreover, in the case of these grains, by being crushed the soft interior is gradually exposed to the juices of the alimentary canal. Thus there is no sudden swelling in the bowels, as sometimes happens when the animal's teeth are entrusted with all the crushing.

Some studs lose a number of horses annually from intestinal calculus or stone. The majority of these stones have some metallic body for a central nucleus, round which salts and fibre have accumulated like fur in a kettle. It is with the idea of preventing such losses that magnets are made use of at some stage in the preparation of feeding mixtures. Unfortunately, many

pieces of iron coated over with dirt seem to escape these extractors, and often intestinal stones show centres consisting of small pieces of zinc-plate, which have most likely come from the sides or bottom of a defective manger.

The soaking of food is resorted to by some horse-owners on the plea that it increases the digestibility of crushed grains. Experimentally, however, this is found to be incorrect. Often horses will "eat up" much better when their food is damped, because they cannot then sort out the corn from the chaff. This may be an advantage in some cases, but it is also a way of getting animals to eat inferior food, with subsequent alimentary derangement.

In winter hot food is often given to animals after a hard day's work. A certain amount of heat is supplied thereby, and the warm mixture is greatly relished, but the digestibility of the food is probably reduced.

The purchase of feeding mixtures ready to put into the mangers should never be resorted to, inasmuch as the ingredients may not be in the proper proportions, although the total weight may be correct. Moreover, inferior stocks of grain have to be got rid of, and there are many ways of deceiving the horses, who are often left to judge the fitness of their food by eating or refusing it. Notice is rarely taken until the damage is done—*i.e.*, when the animals are obviously losing flesh or suffering fatigue easily. Prepared foods are often adulterated, as witness some of the injurious and useless materials which have been shown to be present in some calf foods.

As will be gathered from a previous chapter (Chapter III.—Digestion and Digestibility), the employment of various appetizers has more disadvantages than advantages.

CHAPTER X.

SOME PRACTICAL POINTS IN FEEDING AND WATERING.

When a food mixture has been arranged, suitable in all respects for the animals to which it is to be fed, there are still some important matters to be considered. The chief of these are—(1) the method of distribution of the food, (2) the frequency and times of meals, (3) the times at which water is to be given in relation to meals and work, and (4) the arrangements for week-end feeding.

All these have to be carried out with a view to ultimate economy. The important bearing of these methods of feeding upon the incidence of disease of the digestive apparatus is a point which must not be lost sight of. It is no economy to dismiss the "horse-feeder" if great loss is going to be caused by careless feeding on the part of individual carters. Needless to say, the above remarks do not apply to horses kept for purposes other than profit earning. The whole subject of feeding and watering in relation to work is such a debatable one that methods practised by one owner would be totally condemned by another in the same town, and yet each may base his opinion on the apparent success of his particular procedure.

In these pages are described those methods which the writer, with no pretensions to a monopoly of wisdom in horse management, has found to be satisfactory. Whenever practicable, the provender should be kept in a special chamber. For a large stud of horses this should be a good size, to allow for shooting out the sacked supplies, or in some cases mixing, if the corn and chaff are supplied separately. A loft above the stable, providing it does not allow of contamination by vitiated hot air from below or dust dropping from above, answers quite well. Feeding barrows can be filled from a shoot with an open sleeve on the lower end.

Where three or four horses are kept each of the drivers may be supplied with a small galvanized iron corn-bin, large enough to hold a week's supply. Chaff can be kept in a receptacle to which all have access. If each carter has a key to his bin, then no excuses can be urged when it is necessary to complain of a horse's condition.

In studs of twelve or more animals the feeding should be entrusted to a "horse-keeper," and the carters should not be allowed to have anything to do with feeding. In still larger stables different individuals will carry out the feeding, according to the stable-staff arrangements. A "feeder," however, must be an observant man, and able to notice any peculiarity of appetite in any animal, and vary his serving in accordance with this. Inasmuch as refusal of food is often the first manifestation of sickness, the value of a good "feeder" cannot be over-estimated. When bran mashes are given periodically, attention must be given to the possibility of

"souring"; and to the accumulations of stale food in the corners of the mangers.

The serving basket, or measure, should contain by weight one-third, one-fourth, one-fifth, or one-sixth of the daily ration, according as the animals are fed three, four, five, or six times a day. When the chaff and corn are supplied to the stable mixed together it should be remembered that the heavy corn gradually sinks to the bottom of the feeding barrow as it is being pushed round the stable. For this reason a partitioned barrow with corn in one part and chaff in the other is often used.

The times at which food is given vary greatly, and this is influenced by the nature of the work performed, and the length of time that is allowed for the animals to stand at the manger. The number of times that a horse must be fed daily varies inversely as the concentration of the food. It would be necessary to give an animal several feeds daily of a material poor in proteins, carbo-hydrates, and fats, in order that it might derive enough energy for work. A horse at grass has to be eating most of the time to get a maintenance diet. On the other hand, three or four feeds daily of a concentrated diet will give all the energy required. Again, a certain amount of bulk is necessary for mechanical digestive processes, and it is well to remember the normal physiological variation that may take place in the stomach when diets are changed. Most owners appreciate the value of trying to keep as near as possible to the conditions which the horse's digestive apparatus demands. On the other hand, the equally satisfactory economic results, which appear to be obtained by three,

four, five, or six meals daily, often cause owners to adopt the less laborious systems. The larger the stud and more varied the work, the more difficult will it be to come into line with the natural requirements of the horse. The only general rule that can be laid down is that the daily ration should be as evenly distributed as possible throughout the day, with due respect to work and rest, and that never less than three meals should be given daily. A period of more than six hours without food whilst at work should not be allowed. If such is contemplated a nose-bag should be taken on the journey, and a definite (although it may be short) time set aside for the animal to eat its meal. Many fatal cases of colic have a previous history of *long intervals between meals*, and it is wise to reduce these long fasts.

It is difficult to understand the marked difference in condition which may often be noticed when a stud of *a few* cart-horses is compared with *a large one* where the animals are fed upon the same diet. On careful inquiry it will generally be found that the lower condition of the horses of the large stud is due to three principal factors —viz., irregular working and meal hours, trotting at work, and loss of rest. It is quite easy to understand how these conditions prevent the accumulation of a good supply of muscular and adipose tissue. In a large stable feeding operations begin at 4 a.m., and horses are going out or returning up till 11.30 p.m., leaving very little time for real quiet rest.

Besides the ordinary daily process of feeding, most horse-owners adopt a modified and lessened ration during week-ends and short holidays. This procedure is

theoretically and practically quite good, and it is economical, for it reduces a highly nitrogenous and expensive labour diet down to maintenance value during the period of rest. Moreover, it prevents those diseases which are known to occur after a short rest on a full diet. The usual practice is to give half a bucket of warm bran mash after finishing work on Saturday, and to reduce the corn given at the first two meals on Sunday. Another method is to supply bran instead of corn for the first and second Sunday meals.

During summer various special articles of diet are fed to horses either at the week-end, or at the evening meal on working days. Among these summer feeds may be mentioned various green foods, such as lucerne, and roots, such as carrots. The change is appreciated very much by horses, and is doubtless not without its beneficial effects upon them; commercially, however, many large horse-owners have not been convinced of the value of the practice.

The need and value of supplying rock-salt to horses appears to be recognized in both small and large studs.

Even more debatable than feeding in relation to work and disease is the question of the times at which water is to be offered. The lessons which are to be learned from the natural mode of life and structure of the horse, together with experiments on watering, and the careful observations of horse-owners, are so divergent and opposed to each other that it is not possible to formulate any dogmatic rule as to when a horse should receive his water. Some authorities believe that a horse should be watered *before* feeding; others advise keeping a supply of water always in front of him; whilst a third school maintain

that *after* feeding is the natural time for a horse to take his water. In practice a mixture of some or all of these methods seems to work well and without any apparent ill-effects upon the digestive apparatus. To feed and water at the same time makes extra work, as the mangers get very dirty and sometimes sour. The only general statement that can be made is that the quantity of water required by a horse daily is between six and eight gallons, varying with the season, work, and size of the animal, and that water should not be withheld for very long. With regard to the effects of drinking whilst hot or when sweating nothing assertive can be laid down. Probably it is better for a horse not to drink his fill when very hot; many, however, do, and appear to suffer no harm therefrom. Watering is generally done by buckets filled from taps at the ends of rows of stalls, when the animals are in their standings; or by means of drinking-troughs which the animals pass when going to or returning from work. Public drinking-troughs should not be used, and in the stable-yard a covered trough is advisable to assist in preventing infection by worm eggs and soiling with dust.

The following are four examples of different systems of feeding and watering practised in the same town. The food in each case is scientifically good and economical, and the respective owners are quite satisfied that their own particular procedure is the best, and that it leaves nothing to be desired. It will be seen that the examples include methods where food is given three, four, five, and six times a day. Water is always given after the first meal, but in other respects each procedure is different.

Example I.

No. of horses, 30, vanners. Work: parcel-van. Condition, good. Remarks: One death from colic (twist) in four years.

Weekdays.

6 a.m.	I.	Feed.
7 „		Water.
12 noon	II.	Feed.
1 p.m.		Water.
6 „	III.	Feed.
7 „		Water.

Sundays.

7 a.m.	I.	Chaff and bran.
8.30 „		Water.
12 noon	II.	Bran mash.
6 p.m.	III.	Chaff and bran.
6.30 „		Water.

Example II.

No. of horses, 130, cart. Work: town haulage. Condition, good working. Remarks: Colic very prevalent.

Weekdays.

4 a.m. ...	I.	Feed.
5 „ ...		Some are watered.
6-9 „ ...	II.	Feed.
7 „ ...		Some are watered.
12 noon ...		Water.
12-4 p.m. ...	III.	Feed.
2-4 „ ...		Water.
6-8 „ ...		Water.
6-8 „ ...	IV.	Feed.

Sundays.

6.30 a.m.	I.	Feed.
7 „		Water.
3 p.m.	II.	Feed.
4 „		Water.

Note the irregularity.

A horse fed at 4 a.m. leaves the stable at 5 a.m., and may return to the second feed at 8 a.m., and then not get a third feed until 3-4 p.m. Watering is done at a trough on leaving the stable, and horses which only go out at 7 a.m. get no water until then.

Example III.

No. of horses, 40, cart. Work : town haulage. Condition, good. Remarks : One ruptured stomach and one calculus in four years.

Weekdays.

5 a.m.	...	I.	Feed.
6 „	...	II.	Feed.
7 „	...		Water.
12-1 p.m.	...		Water.
12-1 „	...	III.	Feed.
1 „	...		Water.
6-7 „	...		Water.
6-7 „	...	IV.	Feed.
8.30 „	...	V.	Small feed.

Sundays.

7 a.m.	...	...	I.	Feed.
7.30 „	...	...		Water.
4 p.m.	...	...	II.	Feed.
4.30 „	...	...		Water.

Example IV.

No. of horses, 40. Work : heavy haulage. Condition, good. Remarks : One twisted bowel in two and a half years.

Weekdays and Sundays.

4.30 a.m.	...	...	I.	Feed.
5.30 „	...	...		Water.
6 „	...	...	II.	Feed (smaller).
8-11 „	...	...	III.	Nosebag when at rest.
12 noon	...	...		Water.
12-2 p.m.	...	...	IV.	Feed.
2 „	...	...		Water.
5.30 „	...	...		Water.
5.30 „	...	...	V.	Feed.
7.45 „	...	...	VI.	Small feed.

CHAPTER XI.

FEEDING SICK HORSES.

When a horse is unfit to work on account of lameness or sickness, he no longer requires the full ordinary working diet—in fact, such a diet is generally quite unsuitable. A horse rested on account of lameness is usually quite healthy in other respects, and, therefore, if in good condition, requires simply a maintenance diet. As described in an earlier chapter (Chapter V.), a horse at rest requires only about half the amount of food, reckoned in terms of digestible starch, that a horse at work needs. Further, the food should not contain so high a percentage of protein, or, in other words, the nitrogeneous ratio of the diet may be wider, even down to 1 : 10. At the same time, the animal would not be satisfied with half the bulk of food it had been getting when at work, for the digestive tract needs a certain minimum bulk of food to act upon. Thus it is necessary to reduce the nutritive value of the ration to half that of the working diet, to lessen its protein content, but to feed a larger proportion of the more bulky, less nitrogenous foods to keep up the bulk. These requirements have been kept in mind in arranging the rations suitable for maintenance (p. 47) and these and similar mixtures would be quite suitable for a lame, but otherwise healthy, horse at rest. In many cases a diet of hay with a few pounds of bran is given,

and answers well. Some of the hay is chopped and mixed with the bran, the rest being given long and fed chiefly in the evening. For a horse weighing 1,000 lbs., a suitable amount would be from 15 to 20 lbs. of hay, half as chaff and half long, with 4 or 5 lbs. of bran. If the animal is in poor condition to commence with, advantage should be taken of the rest to put on flesh and condition, and for this purpose additional food, preferably rich in carbo-hydrates or fats, or both, should be given. One or two pounds of maize added to the daily ration will answer the purpose well.

So far as is possible, the diet for a resting horse should be similar to that of Nature, and so green food, either cut grass or artificial grasses—clover, vetches, or lucerne—should be given whenever obtainable. At the same time, care should be taken to prevent the animal becoming too soft in condition if the rest is likely to be only a short one.

For a sick horse suffering from some systemic disease the variation of the diet from that suited to working conditions is of even greater importance. A change is necessary not so much on the grounds of economy, as for reasons connected with the animal's treatment. What the particular ration shall be depends on the disease. In many cases of disease of the digestive tract it may be advisable to give a very restricted diet for some days, something far short of even a maintenance ration. In other cases there is partial or complete loss of appetite, and the chief difficulty is to get the animal to feed at all. At such times professional advice will usually be sought and a suitable diet prescribed, but there are certain general principles which must be observed, and these may here be mentioned.

The supply of water should always be ample, and this

is best insured by keeping water always before the patient. Food should be offered frequently in small quantities, and never allowed to remain in the manger untouched for any length of time. The manger itself should receive attention and be kept scrupulously clean, especially in summer, when damp or cooked foods are very liable to become sour. The height of the manger from the floor may require to be altered in some cases, and it may even happen sometimes that the horse can only feed comfortably with the food near the ground-level. The bran mash as a food for sick horses is deservedly popular, for it is usually appreciated by the patient at first as a welcome change from ordinary dry food, and, if a horse has any appetite at all, is taken with avidity. At the same time, bran-mash is a food of which a horse speedily tires. If the appetite needs coaxing, change of food is all important, and the mash may be varied in flavour by the addition of a handful of maize-meal, pea-meal, bean-meal, oatmeal, crushed oats, or boiled linseed, before mixing. By this means the horse can be kept feeding when he would steadily refuse simple mash. A bran mash is made by putting a sufficient quantity (1 to 3 lbs.) of bran into a perfectly clean bucket, pouring on boiling water, and stirring vigorously till the required consistence is obtained. The addition of a little salt makes the mash more palatable, and it is made sloppy or kept fairly dry according to the needs of the case. After adding the hot water, the bucket is covered with a sack and left till cool enough to be eaten. Care must be taken not to give a mash too hot, or the horse may easily scald his muzzle and mouth. A mash diet is laxative, nutritious, and suitable for the majority of cases of sickness in horses, also during preparation for surgical operations, or before

giving a dose of physic. In nearly all hospital cases save those of lameness, it is advisable to damp the food, and this prevents the horse from picking out the more tasty ingredients of the mixture.

In diseases affecting the respiratory tract, such as pneumonia and pleurisy, and in the allied conditions, such as influenza, strangles, and catarrhal fever, it is very common to find that the horse will take very little food in the early stages. However, when rested and made comfortable and warm in a good, airy box, the animal will often commence to feed a little, and the bran mash modified as described to tempt the appetite is quite suitable. If the horse will take it, a mixture of crushed oats, bran, and chaff, with a handful of linseed, mixed with boiling water, and allowed to cool very slowly, or cooked in a steamer, is very good. At this stage the buccal mucous membrane is dry, and the glandular secretions are lessened, so that a moist diet supplies these deficiencies, and is less likely to provoke coughing than dry food.

The various green fodders, as they come in season, are excellent in most cases, being appetizing, laxative, and generally beneficial. Not infrequently a sick horse will eat greenstuff, whilst refusing everything else, and in some cases freshly cut young grass is the most tempting of all. If even the appetite fails entirely, thirst will often be maintained, and properly prepared hay-tea, linseed-tea, thin oatmeal gruel, or milk, can be given. Hay gives up a good deal of nutriment to boiling water, and hay-tea may be aptly compared with the beef-tea used in the sick-room. Sometimes milk is refused at first, but if water is withheld for a few hours the milk is usually taken, and thereafter no difficulty arises. The practice of horning

or drenching gruel into a sick horse is a very dangerous one, and must be condemned entirely. If there is one occasion on which it is more reprehensible than another, it is when the horse is suffering from any respiratory disease, and frequent drenching under these circumstances will inevitably result in mechanical pneumonia from food getting down the wind-pipe. To keep up an animal's strength, liquid foods can be given as nutrient enemata, and although very little digestion takes place in the bowel, some small amount of nutriment is absorbed. Where the expense is warranted, pre-digested foods* may be given in this way, in which case absorption is easy and the benefit to the animal considerable.

Frequently it happens that where all food put in the manger is steadily refused, a horse will take from his owner or attendant such things as carrots, apples, cabbages, lettuce, and bread; and although the nutriment contained in the quantities given may be almost negligible, the act of mastication and the taste of an appetizing mouthful may persuade the horse to eat from his manger or rack.

In cases of sore throat, in acute laryngitis, pharyngitis, etc., there is often difficulty in swallowing, and here sloppy mashes, linseed-tea, and other liquid foods must be relied on. If swallowing is impossible, rectal feeding becomes necessary if the patient's strength is to be maintained.

Many diseases of the digestive system are due to improper feeding. It may be that one (or more) of the ingredients of the ration is quite unsuitable, and in treating the sickness this substance must obviously be

* Among others may be mentioned Benger's Food and Horlick's Malted Milk.

omitted from the food. Even if not altogether unsuitable, some constituent of the diet may be in excess, and here again it must be reduced to proper proportions. Diseases of the stomach usually benefit by the withholding of all food until such time as the organ has been emptied of gas or ingesta and has recovered its tone. Too early feeding with an easily fermentable material like bran mash may possibly be responsible for prolonging some of these cases. It is well to give scalded hay and the "tea" derived from it before allowing the animal to resume ordinary diet.

In bowel obstruction, after the mass has been moved on, equal parts of scalded chaff and bran make the best diet; but in all the inflammatory conditions of the intestines, which are usually manifested by diarrhœa, the bowel should be rested as much as is consistent with treatment, and large draughts of water should not be allowed. The hypersensitive bowel is readily irritated by indigestible fibre, husks, and the flakes of bran, so that oatmeal, gruel, linseed-tea, hay-tea, milk and eggs are indicated according to the severity of the case. Carbo-hydrates in the form of starch enemata are often given to young stock. As recovery proceeds, more substantial ingredients should be given but bran, on account of its mechanical irritant action, should not be very conspicuous.

In cases of lymphangitis (weed or humour), where it is desired to hasten the action of the bowel and so relieve the lymphatic system indirectly, bran mashes are indicated. After a few days these should be substituted by bran and chaff.

The average number of horses on the sick-list varies considerably according to the supervision that is exercised

over them; usually, however, under the best conditions, it will be from 6 to 8 per cent. The commonest diseases are lameness, respiratory affections, colic, weed, and harness sores. It is truly economical and very advisable to serve out, along with the provender supplied for working horses, special sick rations of long hay, crushed oats, green food, and bran. An outbreak of contagious disease, such as influenza or pneumonia, will speedily demonstrate the value of this procedure.

During convalescence the feeding gradually approximates in kind to that of a working horse, and it is to be remembered that the return of condition and strength will depend largely upon suitable food, a sufficient rest, and graduated exercise. Often a run at grass, if the weather conditions are suitable, will work wonders in an animal much reduced by an illness. Appetite may be improved and the condition generally helped by adding small amounts of malt, or molasses food, or even by the provision of a piece of rock-salt.

Thought and attention bestowed upon the feeding of a sick horse are of immense value, whilst want of care in this respect is fraught with very serious consequences to the animal and so to the owner.

CHAPTER XII.

TABLES—READY RECKONER—EXAMPLES.

In this final chapter are given further tables of assistance in arranging rations and in the practice of substitution, and these are followed by an example illustrating their use. The tables are numbered to follow on after the numbers of tables in preceding chapters in order to avoid confusion.

Table V. shows the variation in the cost of 100 heat units (see footnote, p. 73) according to variations in the market price of each food. It therefore supplies similar data to that given in Table IV. (p. 73), but is adapted to a wide range of prices.

Table VI. shows the comparative values of the different foods by giving the equivalent of 1 lb. of each food in terms of the various other foods. In other words, it enables the reader to see how much maize, or barley, or dried grains respectively, is equivalent in real work-producing power to 1 lb. of oats, and similarly for each of the foods.

Table VII. shows the relative market prices of various foodstuffs at which they provide equal nutritive values. For example, when buying oats at 18s. per 320 lbs., the same nutritive units are being obtained for every £1 expended as when buying maize at 36s. per 480 lbs., or dried grains at 110s. per ton. If oats were at 17s., then

it would not pay to buy maize at anything over 34s., for otherwise each nutritive unit in the form of maize would cost more than nutritive units in the form of oats.

Table VIII. is useful in determining the cost of a ration. It shows the cost of 1 lb. of various foods when the price per quarter, etc., is known.

Table IX. is of great assistance when finding the nitrogenous ratio of a complete ration. For each food is shown the amounts of (1) digestible protein, (2) other digestible nutrients (reckoned in terms of starch), in 1 lb. of the food. To find the nitrogenous ratio of a mixed ration, all that is necessary is to multiplty the "protein" and "non-protein" amounts for each ingredient by the number of lbs. of that substance fed. The ratio is then stated as—

$$\frac{\text{Total digestible protein}}{\text{Total digestible nutrients other than protein}}, \text{ or, } \frac{\text{N}}{\text{F} \times 2{\cdot}3 + \text{C.H.} + \text{D.F.}}$$

The following example is appended to show the method of using the tables for the purpose of calculating the real value of a ration, and of substituting more expensive by less expensive foodstuffs of equal nutritive value:

A stud of 100 horses used for trotting work in town (each horse weighing on an average 1,200 lbs.) is fed on the following daily ration: Oats, 14 lbs.; bran, 5 lbs.; chaff (meadow hay), 14 lbs. per horse.

Questions: (1) Is the ration sufficient for severe work in winter? (2) If insufficient, what foodstuffs can be given to provide sufficient nutrients at the lowest cost?

Now the standard ration for a horse of 1,000 lbs. at severe work must provide the equivalent of 15 lbs. of digestible starch, containing at least 2 lbs. of digestible protein, with a nitrogenous ratio not wider than 1 : 6 (see p. 52). For an animal of 1,200 lbs. the quantity must be increased by 14 per cent. (see p. 48), thus becoming practically 17 lbs. of digestible starch, the nitrogenous ratio remaining the same.

By calculation from Table IX. (p. 114) it is seen that—

Original Ration.	Starch Equivalent.	Digestible Protein.	Digestible Non-Protein Nutrients.
Oats, 14 lbs. } providing	8·40 lbs.	1·26 lbs.	7·63 lbs.
Bran, 5 ,, } providing	2·68 ,,	0·57 ,,	2·26 ,,
Chaff, 14 ,, } providing	4·48 ,,	0·98 ,,	5·13 ,,
Total, 33 ,,	15·56 ,,	2·81 ,,	15·02 ,,

with a nitrogenous ratio of $\frac{2 \cdot 81}{15 \cdot 02} = \frac{1}{5 \cdot 3}$.

Thus Question (1) must be answered in the negative. The food is below the standard requirements by 1·44 lbs. of digestible starch, but contains enough protein.

It is therefore necessary, if hard work is expected of the horses, that the deficiency be made up. This can be done either by increasing the daily allowance of the present mixture, or by substituting other more economical foodstuffs for some of the ingredients in it. Two factors will determine which of these methods shall be adopted —viz.: (1) The bulk or weight of food to be given daily; (2) the question of cost.

The present allowance is 33 lbs. of food daily for each horse, and for horses of this size it would be inadvisable to give much more than this weight of food. Therefore an increased quantity of the present mixture in the amount needed to supply the deficiency is impracticable.

In the matter of cost, on consulting the prices current for the time, it is found that the price of oats (320 lbs.) is 19s.; of maize (480 lbs.) is 33s.; of barley (448 lbs.) is 28s.; of bran (1 ton) is 120s.; and of peas (504 lbs.) is 31s.; whilst meadow-hay is 95s. a load (18 cwt.).

Thus the cost of the present ration per horse *per diem* (see Table VIII., p. 112) is:

Oats, 14 lbs.	9·98d.
Bran, 5 ,, ...	3·25d.
Chaff, 14 ,, ...	7·78d.
	21·01d.

—*i.e.*, 1s. 9d., or 12s. 3d. per week.

Looking at Table VII., p. 111, we see that oats at 19s. are equivalent in value to maize at 38s., whereas we can buy maize at the moment for 33s. Obviously maize will be an advisable purchase. Similarly, barley and peas at the prices quoted are both cheaper than the oats, but bran is dearer. Thus, to cheapen the ration we may substitute suitable amounts of maize, barley, and peas for part of the oats and bran.

It is well to leave some of the oats in the ration, but we will proceed to substitute 10 lbs. of oats by means of 8 lbs. of maize and 2 lbs. of peas, when the ration becomes:

Revised Ration (1).		Starch Equivalent.	Digestible Protein.	Digestible Non-Protein Nutrients.
Oats, 4 lbs.	providing	2·40 lbs.	0·36 lb.	2·180 lbs.
Maize, 8 ,,		6·40 ,,	0·64 ,,	5·860 ,,
Peas, 2 ,,		1·34 ,,	0·37 ,,	1·000 ,,
Bran, 5 ,,		2·68 ,,	0·57 ,,	2·260 ,,
Chaff, 14 ,,		4·48 ,,	0·98 ,,	5·131 ,,
		17·30 ,,	2·92 ,,	16·430 ,,

with a nitrogenous ratio of $\frac{2{\cdot}92}{16{\cdot}43}=\frac{1}{5{\cdot}3}$.

The standard requirements are now provided, but there is still too much bran,* and 4 lbs. of it may well be replaced by barley. By consulting Table VI., p. 110, we see that 1 lb. of bran is equivalent to 0·791 lb. of barley, or 4 lbs. of bran are equivalent to $0{\cdot}791 \times 4 = 3{\cdot}16$ lbs. of barley. We can then omit 4 lbs. of bran and substitute 3 lbs. of barley, when the ration becomes :

Final Ration.		Starch Equivalent.	Digestible Protein.	Digestible Non-Protein Nutrients.
Oats, 4 lbs.	providing	2·40 lbs.	0·36 lbs.	2·18 lbs.
Maize, 8 ,,		6·40 ,,	0·64 ,,	5·86 ,,
Peas, 2 ,,		1·34 ,,	0·37 ,,	1·00 ,,
Barley, 3 ,,		2·02 ,,	0·26 ,,	1·81 ,,
Bran, 1 lb.		0·53 ,,	0·11 ,,	0·45 ,,
Chaff, 14 lbs.		4·48 ,,	0·98 ,,	5·13 ,,
		17·17 ,,	2·72 ,,	16·43 ,,

with a nitrogenous ratio of $\frac{2{\cdot}72}{16{\cdot}43}=\frac{1}{6{\cdot}3}$.

* See p. 61.

This ration should prove satisfactory from the feeding point of view, but the question of cost must still be considered :

Oats, 4 lbs. cost		...	...	2·85d.
Maize, 8 ,,	,,	...	...	6·60d.
Peas, 2 ,,	,,	...	...	1·48d.
Barley, 3 ,,	,,	...	...	2·25d.
Bran, 1 ,,	,,	...	...	0·65d.
Chaff, 14 ,,	,,	...	...	7·78d.
				21·61d.

i.e., slightly over 1s. 9½d., or 12s. 7¼d. per week.

The cost of the new ration is, therefore, slightly in excess of the old one, but it will be more than made good in the condition and efficiency of the horses, which will now receive a ration up to the standard requirements.

It may be pointed out that the nitrogenous ratio falls slightly outside the optimum 1 : 6. To improve this a further 1 lb. of peas might be substituted for 1 lb. of oats or 1 lb. of bran, and the calculation of the value and cost of the new ration under each of these substitutions will afford a useful exercise in the manipulation of the tables.

TABLE V.

Variation in the Cost of 100 Heat Units, With Variation in the Market Price of Foods.

Oats at per 320 lbs.	16/6	17/-	17/6	18/-	19/-	20/-	21/-	22/-
Cost per 100 heat units ...	8/7¼	8/10¼	9/1½	9/4½	9/10¾	10/5	10/11¼	11/5½
Maize at per 480 lbs.	20/-	22/-	24/-	25/-	26/-	28/-	30/-	32/-
Cost per 100 heat units ...	5/2½	5/8¾	6/3	6/6	6/9¼	7/3½	7/9¾	8/4
Beans at per 504 lbs.	30/-	31/-	32/-	33/-	34/-	35/-	36/-	—
Cost per 100 heat units ...	8/6¼	8/9¾	9/1	9/4½	9/7¾	9/11¼	10/2¾	—
Peas at per 504 lbs.	28/-	29/-	30/-	31/-	32/-	33/-	34/-	35/-
Cost per 100 heat units ...	8/3½	8/7¼	8/10¾	9/2½	9/6	9/9½	10/1	10/4½
Gram at per 504 lbs.	24/-	26/-	28/-	30/-	32/-	—	—	—
Cost per 100 heat units ...	7/8¼	8/4	8/11½	9/7¼	10/3	—	—	—
Wheat at per 448 lbs.	24/-	26/-	28/-	30/-	32/-	34/-	36/-	—
Cost per 100 heat units ...	7/3	7/10¼	8/5½	9/0¾	9/8	10/3¼	10/10½	—

Cost per 100 heat units ...	6/8	7/4	8/-	8/8	9/4	10/-	—	—
Rye at per 448 lbs.	25/-	26/-	27/-	28/-	29/-	30/-	—	—
Cost per 100 heat units ...	8/5¾	8/9¾	9/2½	9/6¼	9/10	10/2	—	—
Bran at per ton	90/-	100/-	110/-	120/-	130/-	140/-	—	—
Cost per 100 heat units ...	7/7½	8/5¾	9/3¾	10/2	11/-	11/10¼	—	—
Dried grains at per ton ...	90/-	95/-	100/-	105-	110/-	115/-	—	—
Cost per 100 heat units ...	7/6	7/11	8/4	8/9	9/2	9/7	—	—
Hay at per 18 cwt. (1 load) ...	65/-	70/-	75/-	80/-	85/-	90/-	95/-	100/-
Cost per 100 heat units ...	10/1	10/10¼	11/7½	12/4¾	13/2	13/11¼	14/8½	15/6
Clover hay at per 18 cwt. (1 load)	70/-	75/-	80/-	85/-	90/-	95/-	100/-	105/-
Cost per 100 heat units ...	11/11¾	12/10	13/8¼	14/6½	155	16/3¼	17/1½	17/11¾
Sainfoin hay at per 18 cwt. (1 load)	70/-	75/-	80/-	85/-	90/-	95/-	100/-	—
Cost per 100 heat units ...	11/6¾	12/4¾	13/2¾	14/0½	14/10½	15/8½	16/6¼	—
Oat-straw at per 1,296 lbs. (1 load)	24/-	26/-	28/-	30/-	32/-	34/-	36/-	—
Cost per 100 heat units ...	18/7¼	20/1¾	21/8½	23/3¼	24/9¾	26/4½	27/11	—

TABLE VI.

Equivalents of 1 lb. of Each Food in Terms of Various Foods.

Oats.	Maize (7) and Bean (3) Mixture.	Maize.	Beans.	Peas.	Wheat.	Barley.	Rye.	Bran.	Dried Grains.	Gram.	Oats.	Maize (7) and Bean (3) Mixture.	Maize.	Beans.	Peas.	Wheat.	Barley.	Rye.	Bran.	Dried Grains.
1·00	0·779	0·750	0·857	0·895	0·810	0·895	0·909	1·132	1·111	0·960										
	1·000	0·963	1·100	1·159	1·040	1·159	1·166	1·453	1·426	1·230	1·283									
		1·000	1·143	1·194	1·080	1·194	1·212	1·509	1·481	1·287	1·333	1·038								
			1·000	1·044	0·946	1·044	1·060	1·320	1·296	1·123	1·166	0·909	0·875							
				1·000	0·905	1·000	1·015	1·264	1·240	1·071	1·116	0·870	0·837	0·957						
					1·000	1·104	1·121	1·396	1·370	1·193	1·233	0·961	0·925	1·057	1·104					
						1·000	1·015	1·264	1·240	1·081	1·116	0·870	0·837	0·957	1·000	0·905				
							1·000	1·245	1·220	1·057	1·100	0·857	0·825	0·943	0·985	0·892	0·985			
								1·000	1·981	0·860	0·883	0·688	0·662	0·757	0·791	0·716	0·791	0·803		
									1·000	0·860	0·900	0·701	0·675	0·771	0·806	0·729	0·836	0·818	1·018	
										1·000	1·040	0·807	0·778	0·890	0·933	0·838	0·925	0·945	1·164	1·162

TABLE VII.

The Relative Market Prices of Various Foods at which they provide Equal Nutritive Values.

Oats (320 Lbs.).	Maize (480 Lbs.).	Beans (504 Lbs.).	Peas (504 Lbs.).	Wheat (448 Lbs.).	Barley (448 Lbs.).	Rye (448 Lbs.).	Bran (1 ton).	Dried Grains (1 ton).	Gram (504 Lbs.)
16/6	33/-	30/3	29/-	28/6	25/9¾	25/4½	101/6	103/3	26/10¼
17/-	34/-	31/2	29/10½	29/4½	26/7¼	26/1¾	104/7	106/4½	27/7¾
17/6	35-	32/1	30/9	30/3	27/4¾	26/11	107/8	109/6	28/5
18/-	36/-	33/-	31/7½	31/1½	28/2¼	27/8¼	110/9	112/7½	29/3
18/6	37/-	33/11	32/6	32/-	28/11¾	28/5½	113/10	115/9	30/1¼
19/-	38/-	34/10	33/4½	32/10½	29/9¼	29/2¾	116/11	118/10½	30/10¾
19/6	39/-	35/9	34/3	33/9	30/6¾	30/-	120/-	122/-	31/8¾
20/-	40/-	36/8	35/1½	34/7½	31/4¼	31/9¼	123/1	125/1½	32/6

TABLE VIII.

Cost of 1 lb. of Various Foods at Different Prices.

Oats at per 320 lbs.	16/6	17/-	17/6	18/-	19/-	20/-	21/-	22/-
Cost of 1 lb.	·62d.	·64d.	·66d.	·675d.	·713d.	·75d.	·79d.	·825d.
Maize at per 480 lbs.	20/-	22/-	24/-	26/-	28/-	30/-	32/-	34/-
Cost of 1 lb.	·5d.	·55d.	·6d.	·65d.	·7d.	·75d.	·8d.	·85d.
Beans at per 504 lbs.	30/-	31/-	32/-	33/-	34/-	35/-	36/-	—
Cost of 1 lb.	·72d.	·74d.	·76d.	·79d.	·81d.	·84d.	·86d.	—
Peas at per 504 lbs.	28/-	29/-	30/-	31/-	32/-	33/-	34/-	35/-
Cost of 1 lb.	·67d.	·69d.	·72d.	·74d.	·76d.	·79d.	·81d.	·84d.
Gram at per 504 lbs.	24/-	26/-	28/-	30/-	32/-	—	—	—
Cost of 1 lb.	·57d.	·62d.	·67d.	·72d.	·76d.	—	—	—

Wheat at per 448 lbs.	24/-	26/-	28/-	30/-	32/-	34/-	36/-	—
Cost of 1 lb.	·645d.	·7d.	·75d.	·81d.	·857d.	·91d.	·96d.	—
Barley at per 448 lbs.	20/-	22/-	24/-	26/-	28/-	30/-	—	—
Cost of 1 lb.	·54d.	·59d.	·645d.	·7d.	·75d.	·81d.	—	—
Rye at per 448 lbs.	25/-	26/-	27/-	28/-	29/-	30/-	—	—
Cost of 1 lb.	·67d.	·7d.	·725d.	·75d.	·775d.	·81d.	—	—
Bran at per ton	90/-	100/-	110/-	120/-	130/-	140/-	—	—
Cost of 1 lb.	·48d.	·54d.	·59d.	·65d.	·7d.	·75d.	—	—
Dried grains at per ton ...	90/-	95/-	100/-	105/-	110/-	115/-	—	—
Cost of 1 lb.	·48d.	5d.	·54d.	·56d.	·59d.	·62d.	—	—
Meadow hay at per 18 cwt. ...	65/-	70/-	75/-	80/-	85/-	90/-	95/-	100/-
Cost of 1 lb.	·39d.	·42d.	·45d.	·48d.	·5d.	·54d.	·57d.	·6d.

TABLE IX.

Proportion of Digestible Protein to Non-Protein Nutrients, and Starch Equivalent of 1 lb. of Various Foods.

Food.	Digestible Protein.	Digestible Non-Protein Nutrients.*	Starch Equivalent.
Oats	0·0899	0·5448	0·60
Maize	0·0800	0·7320	0·80
Beans	0·2218	0·5050	0·70
Peas	0·1860	0·5013	0·67
Gram	0·1544	0·4976	0·62
Wheat	0·0904	0·6628	0·74
Barley	0·0870	0·6053	0·67
Rye	0·0825	0·5859	0·66
Broad bran	0·1138	0·4531	0·54
Dried grains... ...	0·1545	0·4369	0·54
Meadow hay (best)...	0·0700	0·3665	0·32
Clover hay	0·0710	0·3515	0·29
Sainfoin hay ...	0·0960	0·3564	0·30
Oat straw	0·0128	0·2783	0·10
Wheat straw ...	0·0089	0·1884	0·01
Carrots	0·0118	0·0846	0·09
Pasture grass ...	0·0245	0·0895	0·10
Vetches	0·0168	0·0899	0·09
Lucerne	0·0299	0·0897	0·09

* The non-protein nutrients are the digestible fats, carbohydrates, and fibre. Before adding, these are brought to equal terms by multiplying the fats by the factor 2·3. In other words, they are represented by the formula $F \times 2{\cdot}3 + C.\text{-}H. + D.F.$

INDEX

THE END

WELLCOME LIBRARY INSTITUTE

BAILLIÈRE, TINDALL AND COX, 8, HENRIETTA STREET, COVENT GARDEN

Maintenance Diet
(Horse of 1000 lbs.)

N.R. 1-8.0 = 6.5 lbs. dry org. matter
7.7

Work diet (moderate exertion)
= 8½ lbs. dry org. matter

Total = 15 lbs.

N.R. = 1-5

Heat of one lb. [illegible] = 8500 [illegible]

1 lb. dry starch = 778 foot tons